Application of QFD methodology to improve the conception of a rack

TRABALHO CONCLUSÃO DE CURSO 2011 – 2012
ESCOLA DE ENGENHARIA DE SÃO CARLOS
- ENGENHARIA DE PRODUÇÃO –

Aluno: Gerard Lombarte Ros
Orientador: Prof. Eraldo da Jannone Silva

Application of QFD methodology to improve the conception of a rack

Gerard Lombarte Ros

Advisor: Eraldo Janonne da Silva

Final monograph of course ending submitted at Engenharia de Produção – EESC-USP – in order to graduate as Industrial Engineer (UPC – Barcelona, Spain)

Focus Area: Product Development Process and fabrication – QFD methodology

USP – São Carlos

June 2012

To my parents, sister, brother, family and girlfriend for making me become the person I am.

Especially to my grandmother, who recently left us and who I am sure that would be so proud of seeing me finishing my engineering degree. Her advice, support and love have made me get where I am.

ACKNOWLEGMENTS

- To my advisor: Prof. Eraldo Jannone da Silva, for giving me the chance to make this project and offering me all his time and required knowledge in order to help me developing it.
- To my parents, for always believing in me, for helping me fulfil my dreams and making me become the person I am.
- To my girlfriend, for being the most wonderful person in the world, for always staying by my side and for giving me the opportunity to fulfil my purpose.
- To Mateus Cecílio Gerolamo for contributing to my work giving advice and helping in everything.
- To all the people I met here at the USP, for being a great support.
- To my all-time friends in Barcelona, for encouraging me to come to Brazil.
- To the República Oligarquia, my family in Brazil, for making me feel home since the first day and for so many unforgettable memories.

TABLE OF CONTENT

RESUME

This project aims to study the redesign of a standard rack of a company in order to achieve improvements through the implementation of the tool named Quality Function Deployment (QFD). This tool is used in the informational design stage inside the product development process and allows studying the customer needs as well as from the competence and the market needs, helping to discover gaps in functionality and quality. In short, it aims to discover all those requirements that still does not meet the product and bring added value to the product, studying them carefully and concluding with possible solutions adapted to the existing model

---

RESUMO

Este projeto tem como objetivo estudar o redesenho de um rack padrão de uma empresa, a fim de alcançar melhorias através da implementação da ferramenta de Desdobramento da Função Qualidade (QFD). Esta ferramenta é parte da fase de projeto informacional no processo de desenvolvimento de produto e permite estudar as necessidades do cliente, bem como as necessidades da competência, juntamente com as necessidades do mercado, ajudando a descobrir as lacunas em termos de funcionalidade e qualidade. Em suma, pretende-se descobrir todos os requisitos que ainda não atendem o produto e trazer valor agregado ao produto, estudá-los cuidadosamente e concluindo com as possíveis soluções adaptadas ao modelo existente.

INTRODUCTION

Electronic technology is an important pillar for the development of any company in the business world. This technology, capable of storing large amounts of valuable information for any of its users, needs and requires generous spaces to be exploited properly.
Hence emerged the rack, a product that offers security, efficiency and comfort for the storage of electronic equipment in any area of work.
Still, like all products, requires constant innovation throughout its life, as the user needs and technology also is altered over time. For this reason, it is interesting to approach the study of this work to search for possible improvements and innovation to make the rack an even more efficient, safe and attractive for all users. [1]

OBJECTIVES

MAIN OBJECTIVES

The main purpose of the study is to redesign a rack from one particular company in order to obtain improvements differenced of the previous versions designs.
To do this, the main objectives can be resumed as:

- Studying the current model of rack, which includes materials, dimensions and components.
- Get the customer voice to remove the product needs required as well as the market needs.
- Translate the customer voice into engineering performance measures.
- Rank by importance this performance measures to optimize with criterion the needs.
- Optimize the final design giving solutions to reach the improvements.
- Make the rack a competitive product.

SECONDARY OBJECTIVES

As secondary objectives, working with QFD process allows developing one of the stages of Product development Process and gives a first contact with the innovation area inside one company. Moreover, the work of redesign does not finish after applying QFD process and give suggestions for future works it is important to facilitate all tasks.

MOTIVATION

Brazil is a country in development and will need this product in many areas and places, from schools and universities to huge multinational companies, which need to organise its data and keep it electronics systems safe.

The product that covers this emerging necessity is a Rack. However, every country has it is necessities and not every product is adapted for every work atmosphere. From this problem arises the idea of redesigning the product and improve its performance, adapting to all type of conditions and give the possibility to be used in all working fields and countries.

In personal opinion, imaging the possibility of redesigning such an important product supposes an amazing challenge and encourages doing all my best to reach the best product approach.

EXPECTED RESULTS

In general terms, the expected results for this study are quite unpredictable as the last recorded rack performance is form one year ago[1]. However, some of them could be the next listed below:

- Discover possible customer segments that have not been provided to the present day.
- Discover design flaws of the current rack.
- Adapt new technologies to the current rack.
- Improve quality design and its functionality.
- Give solutions to the problems encountered.

The mission of applying the QFD process is to prove that the product dispose of all the possible improvements that can be included, not expecting to vary so much their sizing, interior layout but including extra systems system to be differenced from the competition such as mobility system or any type of lighting system.

Furthermore, the desire is also to create a product compatible with the current needs for sustainability and ergonomics. All this to create a product tailored to the needs of its users.

[1] This information appears on the company website http://www.retex.es and is provided by them.

BASIC CONCEPTS OF QFD

PRODUCT DEVELOPMENT PROCESS (PDP) AND QFD METHODOLOGY

[2] In overall terms, product and process development consists of a set of activities based on market needs and technological constraints as well as competitive strategies and product of the firm, through which it is sought to reach specifications to make possible the fabrication of a product or a process organization.

The product development is considered an increasingly critical process to the competitiveness of enterprises, mainly with the increasing internationalization of markets, the increasing diversity and variety of products as well as reduction of their use life.

The efficient launch of new products and quality improvement of already existing products take part of the PDP and are two issues of great importance for the competitiveness of enterprises.

The model is divided into 3 macro stages, divided into stages and activities. These macro stages are known as Pre-development, Development and Post-development; the first and last one are more general and suffer less disruption. Instead, the Development macro stage emphasizes the technological aspects for the definition of the product itself, its features and production process.

Inside the Development macro stage there are 5 substages, which are slightly defined below, each one with defined activities to take into account: informational project, conceptual project, detailed project, production preparation and product release.

This is the first part of development, creates from Project Plan all the future product specifications, those that are desired at the end of engineering activities, which consist on defining the requirements and qualitative information for the future product. In the product design phase, solutions are generated and studied to find the best possible solution capable of meeting all required specifications. Here it is included the QFD methodology.

Once the specifications are defined is time to get a conception of the product in order to know the architecture of the product or process, possible alternative solutions, initial designs, etc…

At the stage of detailed design, product or process design from the previous stage will be detailed and transformed into the final specifications, detailing each item that makes up the product or process. The results of these specifications are a working prototype, a project of the necessary resources (tools and devices) and a project life cycle through the recycling time.

The product is certified depending on the results of the tests done to the prototype. on the same way, the product or process must be homologated and then launched to the market.

The product or process is launched to the market and would be evaluated for a period of time to analyse its performance in all its applications.

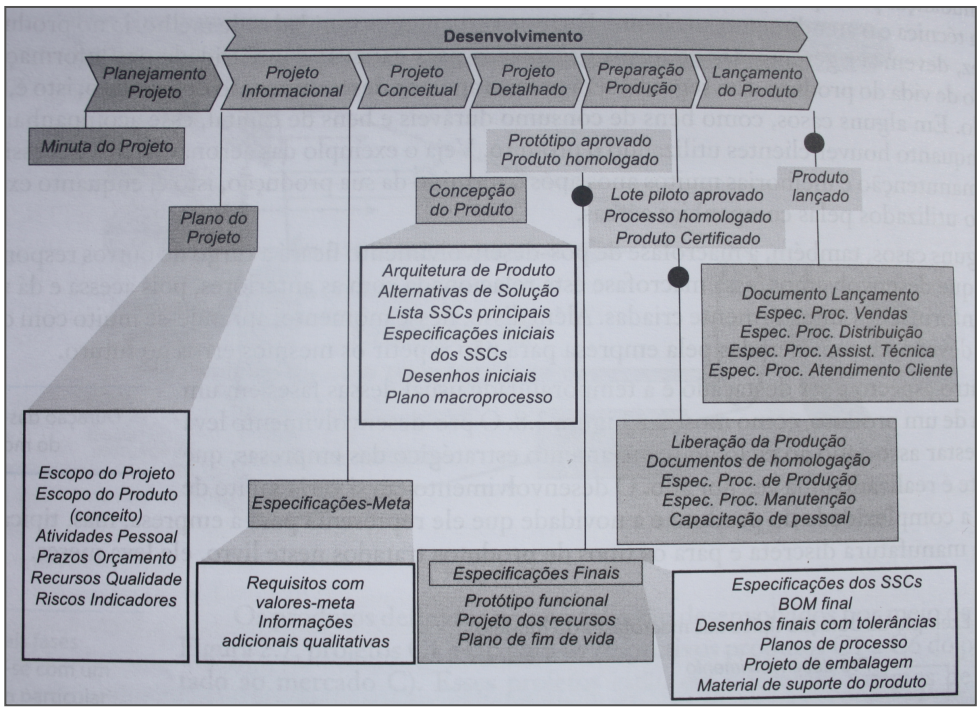


FIGURE 1 – Substages of Development stage

INFORMATIONAL PROJECT

The study of a redesign of the rack Logic 2 using QFD (Quality Function Deployment) is part of the first substage of Development macro stage.

The objective of this stage is, from the information collected in the Planning Project, to develop a set of information as complete as possible called specifications-meta of the product. All this specifications are going to be the base of the process, the evaluation criterion for the next PDP steps and must accomplish all the customer requirements.

So, it is vital to define them clearly to avoid possible bad interpretations or mistakes.
The first movement is to define the product project problem that is going to face and understand all the issues around it. Once the problem is defined, the next position is to define the customers involved with the product lifetime, which includes getting the “voice of the customer” or necessities, to be treated and grouped as customer requirements.
Finally, all the information has to be processed and canalized to extract the important information and design the best solution. [2]

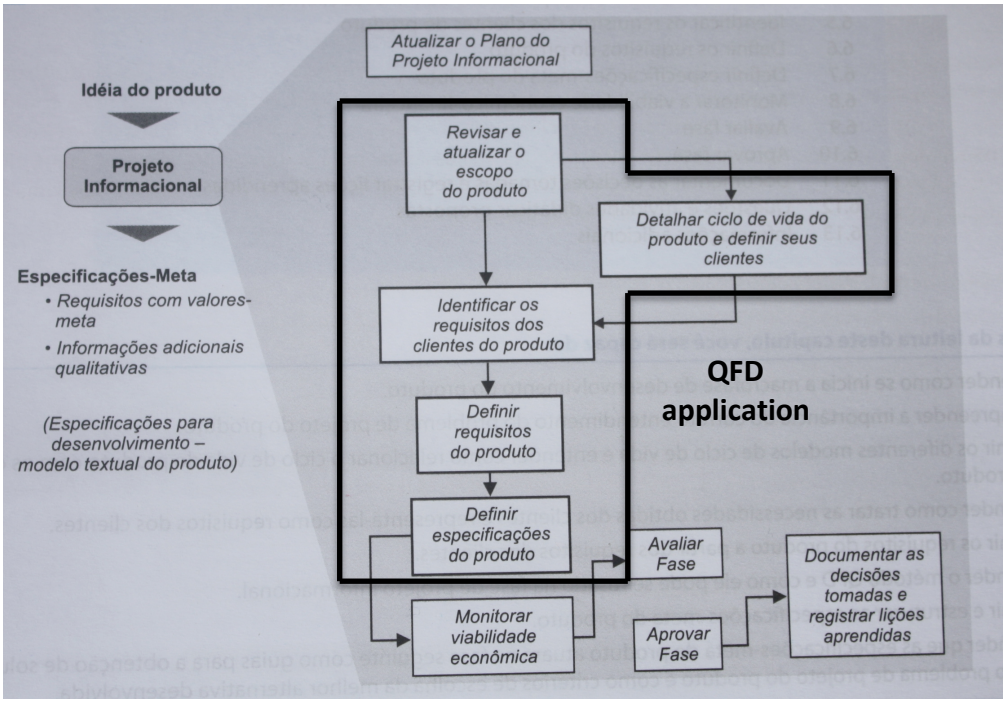


FIGURE 2 – QFD steps inside informational project line

QFD – QUALITY FUNCTION DEPLOYMENT METHODOLOGY

HISTORY

This method was developed and observed in operation in Japan in the early 1980s. The teachings of Akashi Fukuhara of the Central Quality control Association and Dr. Yoji Akao of Tamaqawa University in Tokyo have been prime sources for Japanese information on QFD experience. Using his experience at Toyota as background, Fukuhara follows a pragmatic approach that moves along a logical path from the customers' voice to the production floor. The overall intent is to ensure quality in all stages of the design process, which includes the use of other possible deployment applications inside the QFD process.

There are many proposals of QFD: Akao (1990), King (1989) and ASI (1993). Of these the most used method is the ASI and will continue to be the study of this thesis. [3]

AREAS OF APPLICATION

The QFD matrix idea can be used successfully in other areas not specifically related to products or services, such as business planning site planning and test planning. However, the best area to be used is in product development process (PDP). [2]

DEFINITION

Ronald G.Day defines QFD as: *"QFD is not a tool. It is a planning process"*. [3]
QFD process should be viewed from a very global perspective as a methodology that will link a company with its customers and assist the organization in its planning processes. The purpose is to get in touch with the customer and to use his knowledge to develop products, which satisfy the customer. [3]
QFD is a process that will assist the organization in gaining a customer focus. This is the main objective of QFD. In more detailed terms, enables the establishment of relationships between customer needs and requirements of projects, documenting the benchmarking given as well as detect and verify conflicts between project requirements and the technical difficulties associated with each requirement. So, the "voice of the customer" is the input of the QFD process and the output is the selection of key priority items to improve customer satisfaction.

[1] In resume, the main benefits that the QFD contributes to a project are:

- Reduction of the number of project changes
- Reduced project cycle
- Reducing costs to the start of manufacturing operations (start-up)
- Reduction in warranty claims
- Planning quality guarantee more stable
- Translates customer desires
- Identifies the characteristics that most contribute to the quality attributes
- Allows the perception of those characteristics that should receive more attention

QFD AS A QUALITY SYSTEM

"The characteristics of QFD as a quality system are based in four reasons:

- *Is a quality system that implements elements of Systems Thinking (viewing the development process as a system) and Psychology (understanding customer needs, what 'value' is, and how customers or end users become interested, choose, and are satisfied, etc.).*
- *Is a quality method of good Knowledge or Epistemology (how do we know the needs of the customer? how do we decide what features to include? and to what level of performance?)*
- *Is a quality system for strategic competitiveness*
  - *It maximizes positive quality that adds value;*
  - *It seeks out spoken and unspoken customer requirements, translate them into technical requirements, prioritize them and directs us to optimize those features that will bring the greatest competitive advantage.*
- *Is the only comprehensive quality system aimed specifically at satisfying the customer throughout the development and business process -- end to end. "*[4] ; [5]

METHOD

QFD process (Quality Function Deployment), which will detect malfunctions of the product and identifies possible solutions for improvement. This tool will follow a method to identify the necessities of the customer segments are most affected by the product, translate their requisites into engineering language, present improvements and avoid possible future errors.

The solution needs to be implemented and contrast the range of similarity between the results achieved and the specified on the initial solution or previous designs.

The study methodology of QFD is based on a rational and chronological order of actions for the implementation of new improvements to optimize the rack.

[6] The QFD gives the method to achieve an optimal solution between the customer's requirements and the final design of the product. It follows five major steps all of them related to get the best choice and study one by one.

1. Customer segments: define which kind of customer influences the most.
2. Establish clear understanding of customer context needs (demanded qualities)
3. Establish desired target values for the design
4. Generate new concepts: Implementation in the product solutions achieved
5. Links the product specifications to the manufacturing conditions.

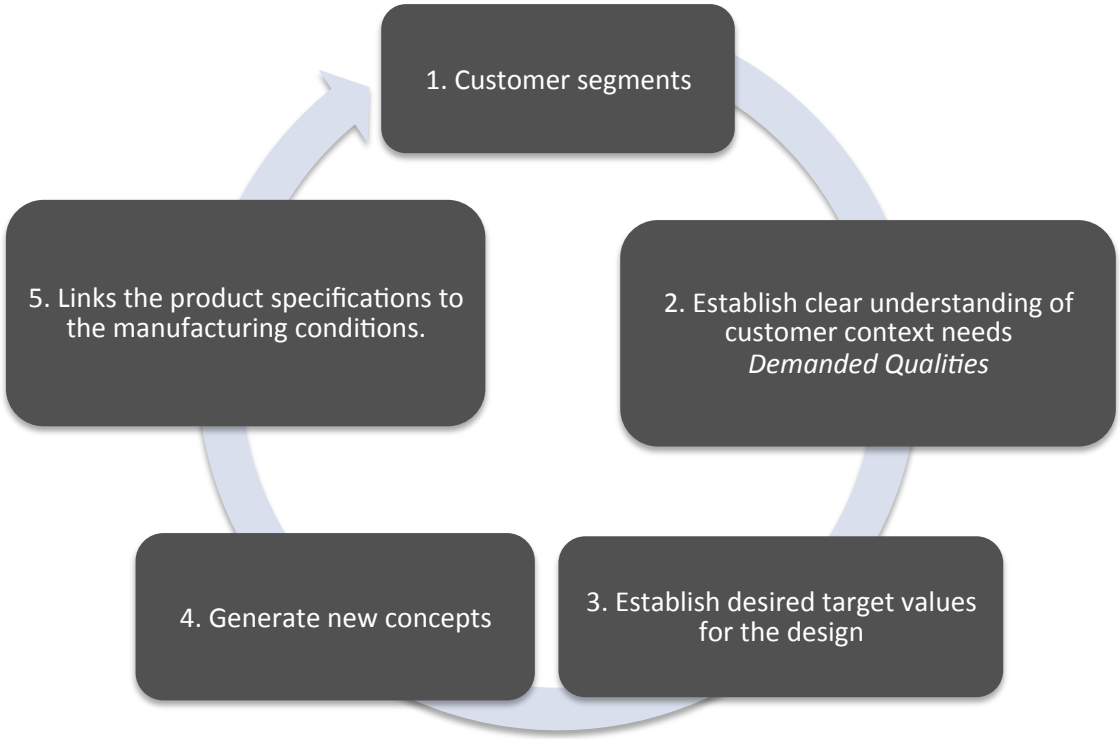


FIGURE 3 – Quality Function Deployment process steps

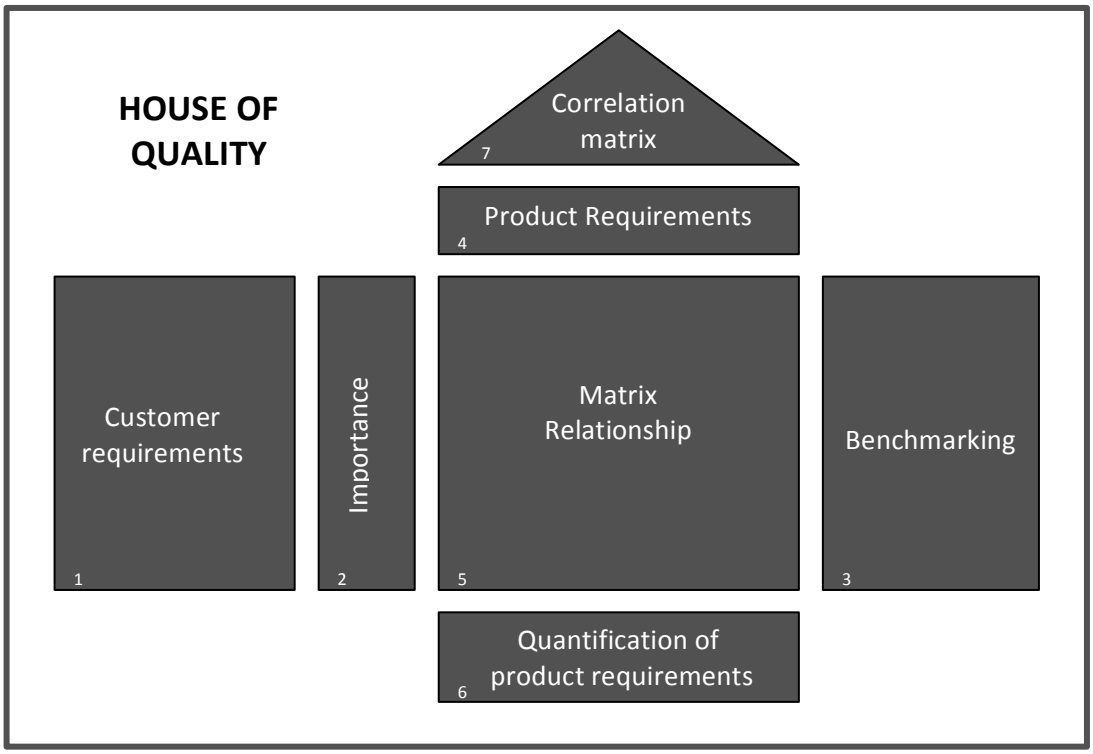


FIGURE 4 – House of quality

[2] The house of quality contains all the information, distributed in an intelligent way to everyone understands and takes conclusions. Each part has his meaning which basics descriptions are:

(1) Customer requirements: establishing who are the consumers and also customer requirements, which means what customer expects of the product. After a selection process using tools such as the AHP method[2], these requirements are transformed into demanded qualities and become the input of the process.
There are many ways to get the "voice of the customer" such as focus groups, interviews, mail questionnaires, product clinics, observations during a period of time or root wants, but the most effective is the one that gets in direct contact with the verbalization of that requisites.

(2) Importance: establish the importance of each customer according to requirements.

(3) Benchmarking: current situation of the product compared to the competition, assessing how many of the customer requirements are being met both by competitors or similar products of the company.

[2] **Method AHP:** a multicriteria decision ranking process that enables the user working with both tangible and intangible factors.

(4) Product Requirements: represents the product's ability to meet customer requirements. It is a translation of customer statements and evaluations into the design team's performance measures.

(5) Matrix relationship: represents the correlation between the customer requirements and the product requirements. For every matrix cell is determined if exists relation or not between them and how much intensity relation.

(6) Quantification of product requirements: set of final specifications for the developing product. In this part of the house quality all the product requirements are sorted by order of importance to take later conclusions.

(7) Correlation Matrix: the interactions between the product requirements are located on the "roof" of the House of Quality and give information of the nature, effects and intensity between them.

Once the product specifications are decided it is time to go on to the next step. As the QFD process never warranties an unsurpassable product as the prototype of the product must be tested and a customer feedback will give always the last but not least opinion of its performance.

On the last step, the product specifications is linked to the manufacturing conditions. The manufacturing database will be formed by the sum of operating conditions and product performance.

RESEARCH METHODOLOGY

PRODUCT DESCRIPTION: RACK

PRESENTATION

A rack is a metal cabinet or shelf for accommodating electronic equipment, computers and communications equipment.

Its measurements are normalized (a width of 19 inches) to be compatible with any manufacturer's equipment and its function is to facilitate the organization of the whole enterprise computer system. It is provided with fans and exhaust fans to prevent overheating as the equipment inside rarely is disconnected. The racks are very useful in a data processing centre, where space is tight and you need to host a large number of devices:

- A server who's housing has been designed to fit the frame of the rack.
- Switches and routers communications.
- Firewall.
- Audio and video.

So, the racks are used to:

- Housing electronic equipment, computer and communications systems
- Server hosting
- Switches and routers hosting
- Firewalls
- Audio and video, plasma screens, DVD, VHS, etc.
- Security of equipment

THE COMPANY

Since its foundation in 1960, the company of rack Logic 2 based in is dedicated to design and manufacture racks and enclosures for the Industrial Electronics and Telecommunications markets.

With distributors for over 36 countries worldwide, is attending and collaborating in top technology projects in the Industrial and Electronics, Railway industry, Cabling, IT-telecommunications, Broadcasting and Datacentres markets. [7]

FIGURE 5 – Rack Logic 2: single door

FIGURE 6 – Rack Logic 2: Double door

CURRENT PRODUCT ESPECIFICATIONS: RACK LOGIC 2

The equipment simply slides on a horizontal rail and fixed with screws. There are also trays that allow non-standard support equipment, as for example, a monitor or a keyboard. Standard measures of a rack under a set of rules, making it:

The vertical columns measures 15,875 millimetres wide each are forming a total of 31.75 mm (5/4 inches). Are separated by 450.85 mm for a total of 482.6 millimetres (exactly 19 inches). Each column has holes at regular intervals called rack units (RU) grouped in threes. Vertically, the racks are divided into regions of 4.445 cm (1.75 inches) tall. In each region there are three pairs of holes along a symmetrical order. This region is called the height, or "U". The height of this standard racks and external dimensions are 200x200mm. As usual there from 4U to 46U in height. Thus, a 41U or 42U rack for example can never exceed the external height of 2000mm. This is achieved in a room with racks virtually similar dimensions, though of different manufacturers. The depth of the frame is not standard, as this gives some flexibility in equipment. However, the dimensions are usually 600, 800 or even 1000 mm. There are also wall racks that meet the format 19 " with dimensions of 300, 400, and 500 mm total, which is very useful for small installations. [7]

Before beginning the main study about redesign the product of RACK LOGIN 2 with the QFD tool, we need to define how is the actual market dealing with the actual product.

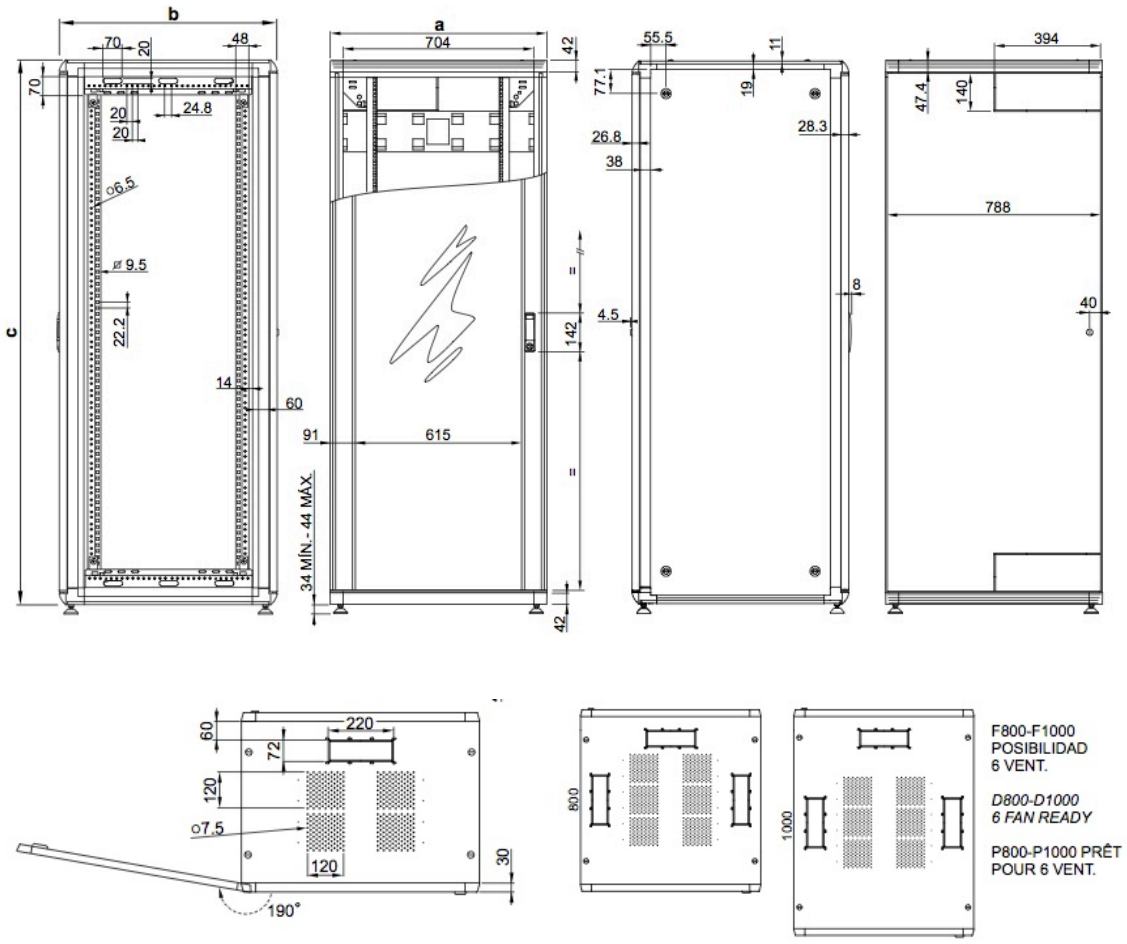


FIGURE 7 – Rack Logic 2 sketch

[7] Here there is a brief description of the product:

» Modular cabinets 19 ", width 600 mm. For installations, telecommunications, IT and industrial electronics. Designed according to IEC 60 297-2, DIN 41494 parts 1 and 7, and EN 20 539-2 ANSI/EIA-310.

The base unity contains:

» External structure in aluminium and bits of high strength cast iron.

» Four 19 "interior profiles movable in depth. Made of steel, thickness 1.5 / 2 mm.

» Front door in aluminium, with safety glass. Handy lock and hinge system "Spring swivel."

» Side panels with quick detachable 1/4 turn.

» Metal rear door lock. System hinge "Spring swivel". Back to pre-machining output cables.

- » Roof ventilated, with quick of 1/4 turn. Integrated cable outlet.
- » Welt of injected ABS corners.
- » 4 adjustable levelling feet.
- » Maximum load capacity divided: 1000 kg (static) / 300 kg (dynamic)
- » Finish: Graphite Grey epoxy paint, corner similar to RAL 5007.
- » Delivery: "Flat-pack." Method of delivery of the product in terms of packaging use

Nowadays exist too many models of racks, each one adapted for each situation. However, every product of the market always can be developed and innovated to give a better performance and uses.

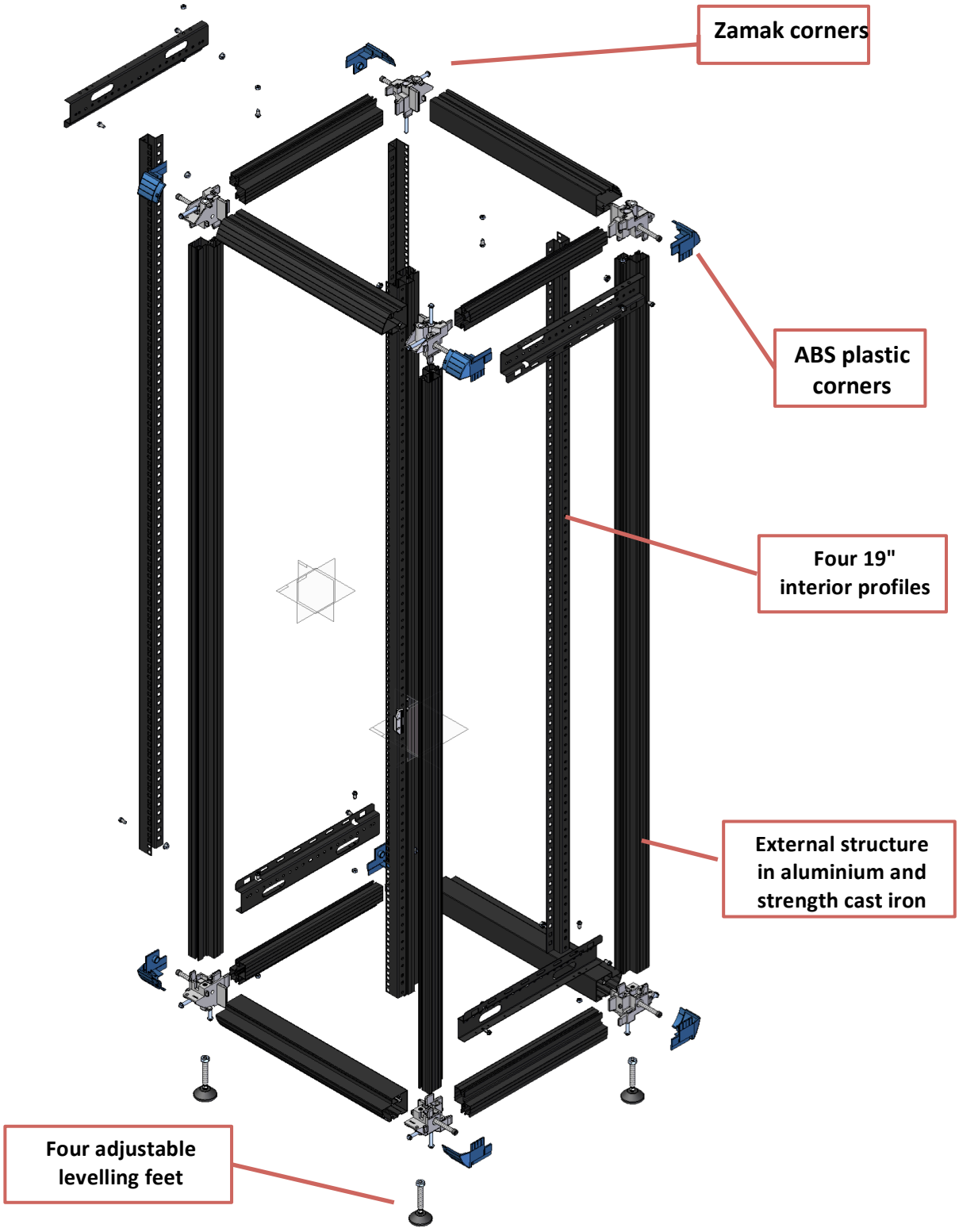


FIGURE 8– Rack Logic 2 interior explosion sketch

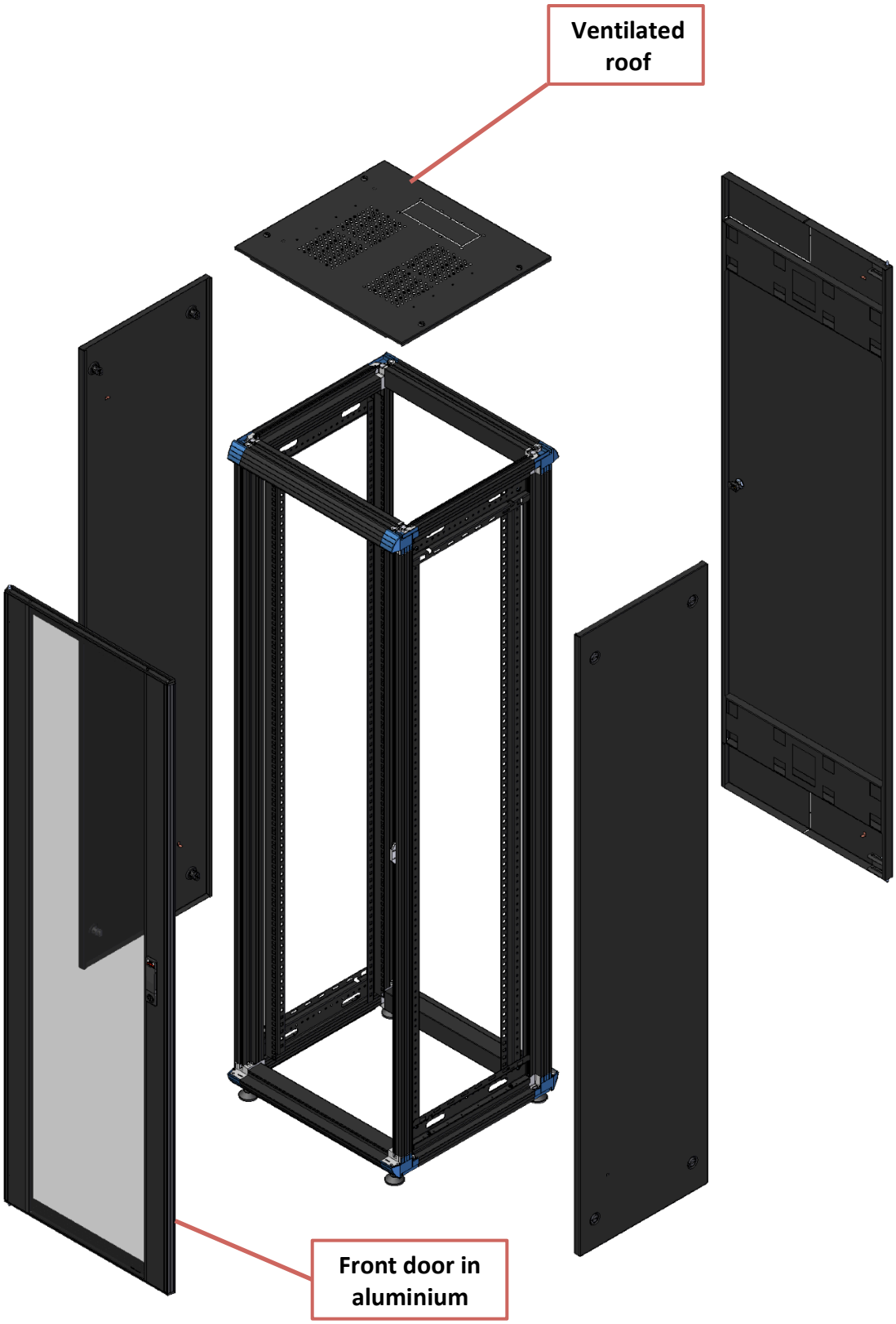


FIGURE 9 – Rack Login 2 external explosion

MATERIALS

The structure of rack is divided itself in three main parts. All of them consist of aluminum alloy profiles, **aluminum alloy 6063,** put it together to form the whole structure distributed on the next disposition:

- » four at the lower base
- » four at the higher base
- » four vertically that make the function of columns.

All three different parts are connected each other by corners made with zamak, which hosts inside the profiles from the structure. To improve aesthetics these corners are eventually covered by other plastic corners.

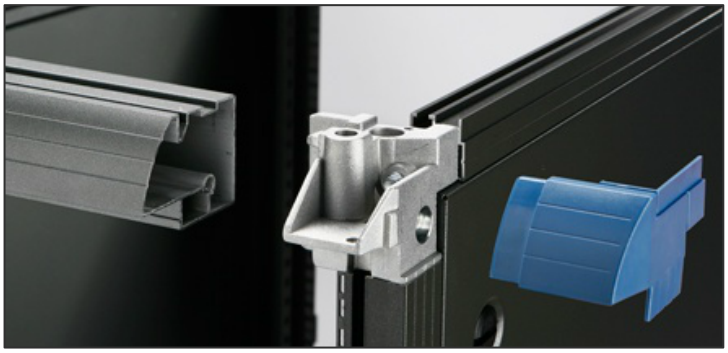


FIGURE 10 – Corners union with zamak corners and plàstic ABS

The structure of the rack is covered by 5 sheet steel:

- » three will end covers
- » two serve on the dock, lower and upper.

The front will be closed by a door consisting of glass and steel. Inside it has a few leaky lanes that allow to anchor the servers, databases or anything else you want to store.

Because of rack's structure shape, aluminum profiles are made with an aluminum alloy which especial characteristics suit perfectly the product:

- » really easy for extrusion
- » it has appropriate mechanical properties
- » good surface appearance
- » good color to anodize

Technical characteristics:	
specific weight (gr/cm³):	**2.70 (N/mm²)**
breaking load:	**165**
yield strength (N/mm²):	**140**
resistance to shear (N/mm²):	**95**
modulus of elasticity (N/mm²):	**69,000**
Brinell hardness:	**42 HB**

Chemical composition:	
Components	***%***
silicon (Si)**:**	0.30 - 0.60
iron (Fe):	0.10 - 3.30
copper (Cu):	0.10
manganese (Mn):	0.30
magnesium (Mg):	0.40 - 0.60
chromium (Cr):	0.05
Zinc (Zn):	0.15
titanium (Ti):	0.20
other:	0.15
aluminum (to the):	rest

FIGURE 11 – Technical characteristics and chemical compositions of structure

» **The steel used in the covers: steel AP02**

This alloy steel, with low carbon content, allows machining plates reducing breakage of the tooling. In addition, although it has a low content in carbon is strong enough to support the loads that you can see under the rack without needing a great thickness of sheet metal and thus get a lighter product.

Chemical composition:	
Components	***%***
carbon (C):	0,0637
manganese (Mn):	0,3350%
phosphorous (P):	0,0065%
sulphur (S):	0,0076%
rest:	iron

Technical characteristics:	
specific gravity (g/cm3):	7.85
breaking load (N/mm2):	343,00
yield strength (N/mm2):	211,00
Rockwell hardness (HRB):	39,0
modulus of elasticity (N/mm²):	20,000

FIGURE 12 - Technical characteristics and chemical compositions of steel used for the structure

» **Zamak corners**: zamak is an alloy of zinc with aluminum, magnesium and copper. This material is hardness and tensile strength for what is considered a very suitable material for making pieces of Union probably will be subject to these efforts.

Technical characteristics:	
specific gravity (g/cm3):	**6.6**
Brinell hardness (HB):	**95**
tensile (kg/mm2):	**32 - 34**
melting temperature (°C):	**386**

Chemical composition:	
Components	***%***
aluminum (Al):	**4**
copper (Cu):	**1**
magnesium (Mg):	**0.05**
rest:	**Zinc**

FIGURE 13 - Technical characteristics and chemical compositions of zamak corners

» **Corners of plastic acrylonitrile butadiene styrene (ABS):** this amorphous thermoplastic is very resistant to shock, has great tenacity and an acceptable chemical resistance. It also has high resistance to abrasion so it is a plastic widely used in the industry.

METHODOLOGY

On this chapter it is going to start the working tool QFD, which it is going to be used as the base of methodology. Each step will focus on a different aspect in the way of RACK's redesign which actions will be completed as the work goes forward.

CUSTOMER SEGMENTS

Before beginning the study is necessary to accomplish one important issue that consists on understanding the costumer, which means that data collected is refined and later will become the input of the next step of the QFD method.
This analysis of the customer starts with identifying the customer segments, their characteristics and establishing the criteria used to prioritize them.

FIGURE 14 – Customer analysis

To do this analysis there exist a list of questions that can be helpful to place the customer in a market and all its requirements. It goes without saying that these issues do not stop being helpful to anyone who wants to focus on the QFD method and get the best result, but in any case the variations between different redesigning projects (of a product, a process, activity, etc.) do not depend on the type of design questions that are formulated.

In order to define the type of client must be taken into account some aspects as the geographical location and the areas of placement of the product you are working with, in this case a RACK, and define their horizons taking care of that information. The aim is to determine a list of features and design improvements for the current product, never losing general sight of the implementation conditions of the country that is going to be destined to.

Summing up, are listed that important questions one should ask himself or to the working group before moving in any direction. In general terms these would be the questions that should include the study:

- Who are the stakeholders for the product of RACK?

  There are too many stakeholders for this product as you can find electronic equipment in many different areas and locations.

- Who are the stakeholders for your organization's product?

  Electronic engineers, product designers, informatics engineers, etc.

- Which customer segments are particularly important to your design?

  To identify all types of customers who will participate for the design of RACK as well as all requirements of the product it will be used two well-known tools in the industrial world, especially in product design and systems.

Nevertheless, all this questions are insufficient to decide the best customer segmentation so exists a tool called segmentation table that provides more extra information and more organized too.

CUSTOMER'S SEGMENTATION TABLE

This tool permits to classify the customer needs, dreams, wishes and expectations. For this, the team should observe customers environment and classify them depending on their characteristics.

For this reason, to get valuable information from customers it has been done some interviews and questionnaires and the results are wrote down in the table:

Who? - Who may use the product? Whom do you see using the product?

Asking or observing the customer (E) or deciding by the organization workgroup (I)

What? - What are the product's uses?

- What else might the product be used for, now and in the future?

Where? - Where do you see the product being used, now and in the future?

When? - When do you see the product being used, now and in the future?

Why? - Why is this product now selected?

How? - How do you see the product being used?

Who?	What?	Where?	When?	Why?	How?
…	…	…	…	…	…

TABLE 1 – Customer Segmentation Table

Next step is to rank all the customer segments that may seem important for the study of rack redesign. The characteristics used for identifying the different customer segments are:

Once customer segments are identified, it is necessary to determine the relative importance of each to decide how much weight to assign to their opinions. For this, is used a criteria based on some characteristics that allows

To evaluate this relative importance it will be used the criteria:

- Easy to satisfy
- Market Size: how many units in proportion each segment is expected to buy
- Cost to support: the smaller is, the more desirable the costumer
- % of electronic equipment dependency for each segment

Once the parameters to choose the customers segments are decided, it is time to rank the criteria using the AHP method (Analytic Hierarchy Process) that will determine the priority importance of each of them.

AHP METHOD – ANALYTIC HIERARCHY PROCESS

The AHP method is a multicriteria decision ranking process that enables the user working with both tangible and intangible factors. The process employs a 1 to 9 weighting scheme for paired comparisons.

RANKING 1 to 9 SCALE

1. Equal importance: the row and column have the same impact upon the higher order need.
2. Between 1 and 3.
3. Moderate importance: experience and judgement slightly favour the row over the column
4. Between 3 and 5.
5. Strong importance: experience and judgement strongly favour the row over the column.
6. Between 5 and 7.
7. Very strong importance: the row is strongly favoured and its dominance is demonstrated in practice.
8. Between 7 and 9.
9. Extreme importance: the evidence favouring the row is of the highest possible order of affirmation.

TABLE 2 – Analytic Hierarchy Process ranking scale

Although exist many others ranking systems, happens that all of them deal with ranking numbers that could be used in an inappropriate way. The AHP method is used to avoid this error as it is recommended using it to create ratio data for ranking.

- At first, is created a matrix to do all the paired comparisons between the criteria aspects using the ranking scale above.
- Next step is to normalize all the columns finding the fraction of the total for each column in order to work without units and get trusty results. To acquire these, all the values are added up on the column order and the value of every cell is divided with its correspondence sum column.
- The rankings of importance for the four criteria are the listed on the column named as average, which value is the mean between al the row values.

The result is a table that contains all the information together. The importance decides which aspect is going to decide the type of customers opinion are affecting the most when it comes to get the "customer voice".

Nevertheless, the method requires doing a pair comparison table to rank the grade of importance for the most important aspect, which customer segment influences the most.

CUSTOMER REQUIREMENTS

The main aim of this chapter is to establish clear understanding of customer context needs, specifically the subjective performance requirements of the rack called demanded qualities, which form the basis of the major QFD analysis. Is about gathering the voice of the customer and understanding the context in which the customers make statements.

The first movement is getting the voice of the customer using the next three techniques: Brainstorming, questionnaires to almost 20 companies to get their opinion and finally implementing the Blitz QFD.

To establish the real demanded qualities and group all the information gathered on the previous step, its needed to remove customer needs using a technique, especially by affinity diagrams. Then, to organize all the information and have a global and clear vision of all the requirements is used the Tree diagram.

Finally, and the most important moment of the process, the customer needs have to be prioritized. To do this on the best way, and repeating from past chapters, the AHP method and Ishikawa diagram or Failure diagram.

GETTING CUSTOMER VOICE

There are many ways to get the voice of the customer, although not all of them have the same result. In this case, is going to present three of them as they give more than enough information to the project.

BRAINSTORMING

This creative tool for management is one of the most useful for all kind of studies and projects. During a minute all the organizing group work has to express all things that past through their minds and write it down on a paper or an easel pad. Don't need to be things talked with sense because after this storm of ideas the organization group will discuss everything and choose what can help or not. Nevertheless, the activity should be done with some rigor to obtain optimal results.
Once possible customer segments are identified, is well worth to identify which are the most importance needs for them and rank to decide which of all are the most useful and optimal to the product.

QUESTIONARIES

As it is said, there are many ways to get the useful information. However, sending a questionnaire to the customer and other companies as if were real interviews is very recommended as all information is already write it down. All the information is collected, classified and listed down on a chart.

BLITZ QFD

Blitz QFD methodology allows us to align our resources with the real customer needs and is a very handy tool that requires no software or specific tools (such as the House of Quality) to deliver results (though both the software and the House Quality can also be very useful additions to the Blitz QFD)

The Blitz QFD consists of 7 steps:

» **Get the voice of the customer**.

This means: "Go to the scene, go to where the action is going on" so the customer voice cannot be heard from long distances. You need to visit, ask, ask again and ask again until you understand the verbalization of what the customer want, what means getting the direct quote of what the client said, write it between quotes and exactly the same way the client said.

» **Sort verbalizations**.

The objective of this step is to classify the verbalizations into related topics, as customer direct voice, complementary or opposed. By classifying the utterances, we are also looking for patterns that allow us to better understand customer needs. Importantly, this is not a quantitative but qualitative study. So at this stage, we are not interested in the statistics of how many utterances exists of each type but rather classified verbalizations to get real customer needs.

» **Structuring customer needs**.

Once verbalizations are classified, we have to extract from them the customers needs. This is a critical step, as some are explicit and clear, but others are implicit and some may seem absurd to us. However, it is vital to remember that we are looking for real customer needs, not "our version of the client's needs".

» **Analysing the Structure of Customer Needs**.

There are needs that have dependency relationships so can appear second needs that seem to not exist. Is helpful to use a table for ease of explanation and traduce customer requirement into valid and useful information.

In the QFD, the interest is in the needs of higher rank so these are the ones that have most impact (positive or negative) on our customers.

» **Prioritize Customer Needs**.

This involves establishing what the needs are most important to our customers (Well, Nice or Cheap?). The best way to do this, once needs are identified and stratified, is asking directly to customers.

» **Expand Prioritized Needs**.

Once we have identified prioritized needs of our customers, then we must identify which parameters, processes or elements of our system contribute more to fulfil (or not meeting) these needs. For really improving, this step must always focus on all those affecting the more priority needs.

» **Scan only priority relations in detail.**

In evaluating our product or service, the most important points are those that impact directly to the priority needs. All our resources must be focused on these points as the quality of our products and services is determined by the extent that we align the value of resources to priority customer needs.

REMOVE AND ORGANIZE CUSTOMER NEEDS

KANO MODEL

The Kano distribution is used to understand the importance of functions and features (called needs) for the customer. These functions are demanded qualities and they are sorted into one of the three next categories according to the importance that the customer gives to them in the design final product:

- **Basic needs**

  Fundamental needs that the product requires, as without them the product cannot result. The customer does never express this kind of needs.

- **Performance needs**

  Provide an increase in satisfaction as performance improves. The customer uses to express this kind of needs

- **Excitement needs**

  This kind of need cause immediate happiness. Further increases in performance cause more delight. There is one sentence that defines this concept:
  "*Creation of some excitement features in a design will differentiate your product from the competition."* [6]

AFFINITY DIAGRAMS

This technique provides structure for verbal data by creating natural clusters or groups. On this way, all the customer data is grouped into groups, distributed graphically.
This association is useful if is made quickly without thinking too much, and after it, it is recommended to redistribute the statements to get the best result.
All groups contain two statements at least, so is the minim number to become a demanded quality. These demanded qualities usually are the group name, as they define the content of each group and this makes easy identifying all the customer requirements.

Moreover, this tool allows discovering requirements that can be missing for every group just answering the question bellow:

" If this is the name of the group, what elements should be included but are missing?" [6]

TREE DEMANDED QUALITY DIAGRAM

The application of both affinity diagram and tree demanded quality diagram gives a good general vision of how customer needs are distributed and lets group them according the topic they refer to. The tree demanded quality diagram is an analytical tool within the QFD process that helps us to establish causal relationships between different needs of the customer, always after removing all needs from the voice of the customer (VOC).

Its mission is to:

- Establish causal relationships between customer needs.
- Identify customer needs implied or not considered.
- Establish levels of customer needs (which is very useful since it is only valid to compare and prioritize customer needs that are on the same level).

To build the tree is good to consider some details:

The affinity diagrams demanded qualities are the first tree diagram level. Anyway, it is recommended to have 3 levels of maximum requirements.

Normally, tree diagrams typically have between 5-10 different branches. Both tools work in the most general vision and they are comparable each other from the customer viewpoint. To check the logic of a tree diagram, you can ask how to fulfil the need and why you need to do this (from right to left).

In all these cases the logic is valid. Identify whether to add more requirements to complete the tree. Often customers do not identify some needs, so this is the best time to add them, validating their logic as in the previous section. This brings up a list of needs stratified at the appropriate level and allows us to ask the client to assign a priority to know which ones we should focus efforts.

PRIORITIZE CUSTOMER NEEDS

Once the customer requirements are grouped, it is time to define which of them are most important comparing each other using the AHP methodology.

First, it is done a table with all pair of requirements ranked by importance. As the AHP method requires, the values from the table should be normalised to get the final ranked average results.

Now, it is necessary to rank the requirements that are contained on the demanded quality groups as well. So, once again, the AHP method is applied to each pair of requirements contained in every demanded quality group to know which are the needs that have most importance when designing the rack.

HOUSE OF QUALITY

The House of Quality is the last but not less important step to traduce all the customer information in the real design parameters of engineering. This House is divided in many parts that are going to be treated separately to show how is the procedure manipulation of information and understand all the process.

DEMANDED QUALITIES

In every product design process are mentioned the product design requirements. It is time to select, form the affinity diagram agrupation, which demanded qualities are the most important for the design process.
But the question is which demanded qualities should the organization select?
After prioritizing all demanded qualities with the AHP methodology and basing on the affinity diagram groups, it is time to do the same with the sublevels of each demanded quality and rank them by importance. However, it appears that some of them are relatively negligible in comparison with the ones that truly have an important impact on the design process. So, in the case of the rack design, from al the containing requirements in each demanded qualities listed only are going to be taken in care the most important one's.
The mission is to get from every different group the final and most important requirements.

When it comes to the Kano model classification, it is not only necessary but also interesting to not include the basic needs, as they are such important that no one can choose or reject the appropriate ones.

QUALITY PLANNING TABLE

The Quality Planning table is used to establish a parameter called *Composite Importance* for each demanded quality.
Begins with the customer input of demanded quality, importance for each one, and the subjective evaluation of product performance for several competitors.
To deal with all the necessary information of this part of the House of Quality construction is necessary to divide in two diferent parts, Quality Planning table (I) and (II).

QUALITY PLANNING TABLE (I)

In the first part, the aim is to get the different evaluations of the different final performances chosen for the final design of the rack.
To do this evaluation of the product performance each competitor has the same weighting scheme scale from 1 to 5.

5 → demanded quality is a primary influence upon the decision to buy … 1 → demanded quality has no influence upon the decision to buy

The result is the identification of the best industrial performance.
After this, it is calculated the weighted customers satisfaction by multiplying Importance of each demanded quality to the relative satisfaction of each, customers and competitors. All values give a general idea of the grade of satisfaction, as looking and deciding using only the particular values of each demanded quality is not the right way to get a valid result.

QUALITY PLANING TABLE (II)

The traditional design process must choose directions for improvement and decide what aspects of the product will be used to promote sales. This part of the "House" provides a structure for the discussions and a means to display the summary of these decisions.
Now it is time to compare all the opinions between the customer and its competitors and define the different aspects that need to be improved and reached in the real design.
There are some concepts to know before starting:

- **Target performance**: is influenced by the organization's performance in relation to competitor's and the customer's demanded quality importance. However, trying to improve every aspect of the rack product is not an efficient way to increase market share.
- **Ratio of improvement**: it results from the division between the Target value and the company of rack Logic 2 customer opinion.
- **Sales points**: are the specific features that will distinguish a product from the competition. It needs to focus the energy on particular points that will make Rack outshine the competition in certain areas.

  The punctuation ranking follows the next rules:

1.5 = reserved for demanded qualities that will distinguish the rack Login 2 from the competition's.

1.2 = reserved for the nice to have but not the critical.

1.0 = for all the demanded qualities vital for the rack's competition

» **DQ Composite Importance**: is equal to demanded quality importance times Ratio of improvement times Sales points.

PERFORMANCE MEASURES

Up to this point, all information has been related to the customer's demanded qualities. However, this information specified in the customer's language is not very specific, so all the ideas must be changed to a more technical language due to evaluate alternative designs and to predict the satisfaction of the customer.

"A performance measure is a technical measurement evaluating the product's performance of a demanded quality or a function." [6]

RELATIONSHIP MATRIX

The predictive relationship between performance measures and demanded qualities is critical for the transformation of demanded qualities into objective design language. Identifying the strength of predictive ability of each performance measure for each demanded quality is rarely part of traditional design processes.

To fill the gaps of the matrix relationship it is necessary to take into consideration the next question:

"If I know the value for performance measure X, how well will it predict the customer's satisfaction with the product's ability to satisfy demanded quality Y?" [6]

To evaluate the range of importance for each intersections it has been used the 3 kind of symbols typically used in these part of the house of quality:

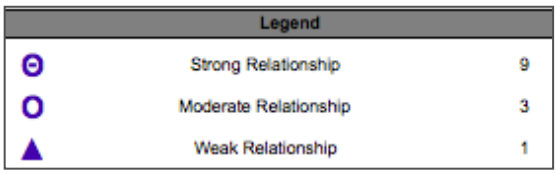


FIGURE 15 – Ranking of importance

When one intersection is a blank cell that means that there is no relation between the demanded quality and the performance measure.

PRODUCT PLANING TABLE

Before establishing the design targets, the relative importance of the performance measures must be calculated using the results from the matrix relationship.
There are two parameters to calculate to get this relative importance: the weighted importance and the relative weight.

- **Weighted importance:** The weighted importance is equal to the sum of the product of the strength of the relationship from the columns of matrix relationship times the related DQ Composite Importance score in the last column.
- **Relative weight:** The relative weight gives the percentage of importance from the total weight. Compared with the parameter above gives much information and is the really one that determines the character of importance.

SELECTING TARGET VALUES

As is doing a model upgrade for an existing product design, can exist possible design conflicts among the performance measures. These conflicts would force tradeoffs between competing target values. In order to identify these possible conflicts, answering the following general questions can help:
- How important is the performance measure?
- How does the performance measure relate to the corporate image?
- What do you think the competition is developing?
- What resources are available?

Nevertheless, sometimes the most important performance measure may not get a target for improvement because the product is already better than the competition and there not seem to be any developments in the near future.
To rank all performance measures is used the next criteria:

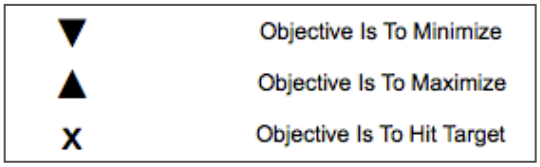


FIGURE 16 – Ranking of target

IDENTIFYING PERFORMANCE MEASURE CONFLICTS

This represents the "roof" of the House of Quality and documents positive or negative influences between the performance measures. Thus aims to find if there is negative or strongly negative, positive or strongly positive impact between rack performances measures that can compromise the design unless these negative impacts are designed out.

Asking the following question helps to clarify relationships among design measures:

" If performance measure X is improved, will it help or hinder performance measure Z?"

Here are listed the two particular cases that can appear during the analysis:

1. Both larger values for X and Z are better. If X is increased and causes Z to increase, then X has a positive or strong positive influence on Z.
2. Larger values for X but smaller values for Z are better. If X is increased and causes Z to decrease, then X has a positive or strong positive influence on Z.

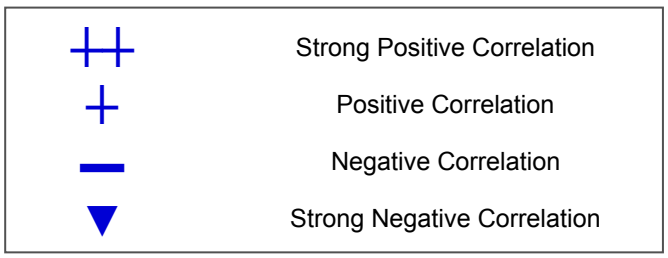


FIGURE 17 – Ranking of correlation

Once this part is done, the response to all this method will end in the TRIZ tool (Theory of Inventive Problem Solving), which analyses the all this possible conflicts and try to find the motive of them. But, this is not included in our study so it would be a possible suggestion to do for future works.

RESULTS AND DISCUSSION

CUSTOMER SEGMENTS

CUSTOMER'S SEGMENTATION TABLE

Who?	What?	Where?	When?	Why?	How?
Teachers	Teaching	School	From 9 to 17h	To teach children computer skills	The computers need to be charged every day during the night.
Architects	Designing	Street	From 9 to 17h	To keep designs and sketch safe	While they are checking their building works and consulting details and information
Consultant	Searching or consulting	Office	From 9 to 17h	To keep data base safe and consult	While working with projects that need to be contrasted with some information
Informatics	Implementing	Office	From 9 to 17h	To organise electronic equipment and keep data base	They use it to organise all the office informatics equipment, connecting all of them each other
Medical Centres	Medical operations	Hospital	Always during 24 hours	To keep patients data profile	When new patient arrives, to arrange medical visits,..
Home servers	Entertaining	Home	Afternoon from 18 to 24h	To use the printer, DVD, VHS,…	Kids play computer, use internet, see a film,..
Banks	Consulting	Office	All year during 24h	To keep safe all the customers information and control money movements	Every time a customer asks for movements of money or keeping the accounts ready to day.

Once customer segments are identified, it is necessary to determine the relative importance of each to decide how much weight is assigned to their opinions.

After collecting this information, from the entire customer segments are chosen the ones that may seem important for the study of rack redesign. The characteristics used for identifying the different customer segments are:

- Familiarity with the product
- The kind of use given to the product
- Frequency of manipulation
- Space to be located

So, taken all this into account, exist many group of sectors that deal with the rack such as Teachers, Architects & engineers, Consultants, Informatics, Banks… and all have been considered when redesigning the product.

However, not every segment has the same importance. To know which are the most important one's they have to be ranked using the AHP method.

AHP METHOD – ANALYTIC HIERARCHY PROCESS

Matrix for all the paired comparisons for criteria:

	Familiarity with the product	Product use	Frequency of manipulation	Place of product location
Familiarity with the product	1.00	0.33	0.20	0.33
Product use	3.00	1.00	0.20	0.14
Frequency of manipulation	5.00	5.00	1.00	0.33
Place of product location	3.00	7.00	3.00	1.00
Total	12.00	13.33	4.40	1.80

Next is to normalize all the columns finding the fraction of the total for each column.

	Familiarity with the product	Produ ct use	Frequency of manipulation	Place of product location	Total	Average
Familiarity with the product	0.08	0.03	0.05	0.18	0.34	**0.085**
Product use	0.25	0.07	0.05	0.08	0.45	**0.11**
Frequency of manipulation	0.42	0.37	0.22	0.18	1.19	**0.297**
Place of product location	0.25	0.53	0.68	0.56	2.02	**0.505**
Total	1.00	1.00	1.00	1.00	4.00	1.00

The rankings of importance for the criteria are the listed on the table above on the column Average. This means that

- Place of product location represents the 50,5 % of the importance
- Frequency of manipulation follows with 29,7%
- Product use has 11%.
- And the last criterion, not too far from the third is Familiarity with the product with 8,5%.

So using the results form the AHP method and analysing all the criteria for every customer segment appears that the most desirable customer segment is the one wich gives a huge importance to the location of the product.

Following the criteria appears that the segment that has major problems with location are the medical centres to avoid any contact with patients, architects when working in the buildings constructions and last consultants and informatics which especially dedicate a room for this kind of equipment as racks. This values permit to focus in aspects that affect these segments more than others.

CUSTOMER REQUIREMENTS

GETTING CUSTOMER VOICE

Customer requirements are the basis of our study, as the mission is to get the best product for these requirements, always being careful of what is already designed and what can be improved. After applying the three techniques explained on the research methodology chapter, which are brainstorming, questionnaires and the Blitz tool, these are the requirements that result for the rack:

	RACK requirements
A.	*Hard and resistant structure*
B.	*Sustainable recyclable structure*
C.	*Work with high temperatures*
D.	*Easy to assemble*
E.	*Easy assembly instructions*
F.	*Easy to use, intuitive*
G.	*Basic design*
H.	*Minimum space occupied*
I.	*Little visual impact*
J.	*Dimensions adapted to human limitations*
K.	*With mobility system*
L.	*Access Controls*
M.	*Interior lighting*
N.	*Unseen automatic cooling system*
O.	*Physical protection for devices*
P.	*Maximize load capacity*
Q.	*Visibility of the interior*
R.	*Light weight*
S.	*Correct distribution of devices*
T.	*Good cable administration*
U.	*Opening 360°/ easy access to devices*
V.	*Impermeable*
W.	*Soundproof*
X.	*Easy maintenance*
Y.	*Economic price*
Z.	*Easy replacement*
AA.	*Visible electrical connexions*
AB.	*Fireproof*

REMOVE AND ORGANIZE CUSTOMER NEEDS

KANO MODEL

Here there is the classification of customer needs according to Kano's model.

Basic needs	
A.	*Hard and resistant structure*
C.	*Work with high temperatures*
D.	*Easy to assemble*
F.	*Easy to use, intuitive*
J.	*Dimensions adapted to human limitations*
S.	*Correct distribution of devices*
V.	*Impermeable*
AB.	*Fireproof*

Performance needs	
B.	*Sustainable recyclable structure*
E.	*Easy assembly instructions*
G.	*Basic design*
H.	*Minimum space occupied*
K.	*With mobility system*
N.	*Unseen automatic cooling system*
O.	*Physical protection for devices*
P.	*Maximize load capacity*
R.	*Light weight*
T.	*Good cable administration*
X.	*Easy maintenance*
Z.	*Easy replacement*
AA.	*Visible electrical connexions*

Excitement needs	
I.	*Little visual impact*
L.	*Access Controls*
M.	*Interior lighting*
Q.	*Visibility of the interior*
S.	*Correct distribution of devices*
U.	*Opening 360°/ easy access to devices*
W.	*Soundproof*
Y.	*Economic price*

AFFINITY DIAGRAMS

STRUCTURE

A. Hard and resistant structure
B. Sustainable recyclable structure
C. Work with high temperatures
V. Impermeable
W. Soundproof
AB. Fireproof

TECHNICAL ASPECTS

P. Maximize load capacity
Q. Visibility of the interior
R. Light weight
S. Easy distribution of devices
T. Good cable administration
U. Opening 360°/ easy access to devices
AA. Visible electrical connexions

ASSEMBLY AND USE

D. Easy to assemble
E. Easy assembly instructions
F. Easy to use, intuitive

MAINTENANCE AND REPLACEMENT

X. Easy replacement
Y. Easy maintenance
Z. Economic price

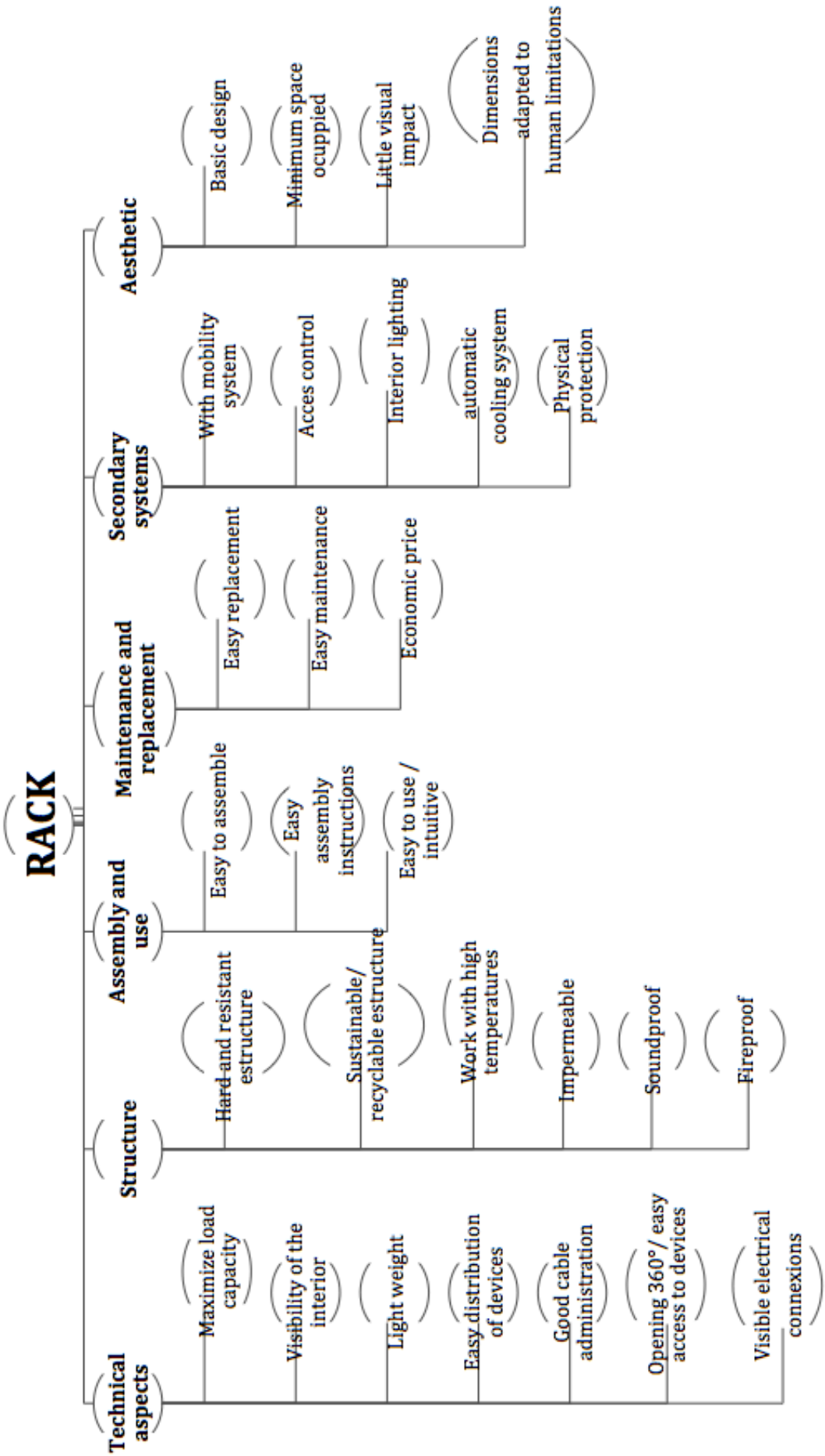
AESTHETIC

G. Basic design
H. Minimum space occupied
I. Little visual impact
J. Dimensions adapted to human limitations

SECONDARY SYSTEMS

K. With mobility system
L. Access Controls
M. Interior lighting
N. Automatic cooling system
O. Physical protection

TREE DEMANDED QUALITY DIAGRAM



PRIORITIZE CUSTOMER NEEDS

With the customers requirements grouped depending on the issue they are involved in, it is time to define which of them are the most important comparing them each other using another time the AHP method.

AHP METHOD

	TECHNICAL ASPECTS	STRUCTURE	ASSEMBLY AND USE	SECONDARY SYSTEMS	MAINTENANCE AND REPLACEMENT	AESTHETICS
TECHNICAL ASPECTS	1	2	7	5	7	9
STRUCTURE	0,5	1	3	3	7	5
ASSEMBLY AND USE	0,14	0,33	1	2	3	5
SECONDARY SYSTEMS	0,2	0,33	0,5	1	3	3
MAINTENANCE AND REPLACEMENT	0,14	0,14	0,33	0,33	1	5
AESTHETICS	0,11	0,2	0,2	0,33	0,2	1
TOTAL	2,09	4	12,03	11,66	21,2	28

	TECHNICAL ASPECTS	STRUCTURE	ASSEMBLY AND USE	SECONDARY SYSTEMS	MAINTENANCE AND REPLACEMENT	AESTHETICS	TOTAL	AVERAGE
TECHNICAL ASPECTS	0,48	0,50	0,58	0,43	0,33	0,32	2,64	0,44
STRUCTURE	0,24	0,25	0,25	0,26	0,33	0,18	1,50	0,25
ASSEMBLY AND USE	0,07	0,08	0,08	0,17	0,14	0,18	0,72	0,12
SECONDARY SYSTEMS	0,10	0,08	0,04	0,09	0,14	0,11	0,55	0,09
MAINTENANCE AND REPLACEMENT	0,07	0,04	0,03	0,03	0,05	0,18	0,38	0,06
AESTHETICS	0,05	0,05	0,02	0,03	0,01	0,04	0,19	0,03
TOTAL	1,00	1,00	1,00	1,00	1,00	1,00	6,00	1,00

DEMANDED QUALITY	RANKING
TECHNICAL ASPECTS	0,44
STRUCTURE	0,25
ASSEMBLY AND USE	0,12
SECONDARY SYSTEMS	0,09
MAINTENANCE AND REPLACEMENT	0,06
AESTHETICS	0,03

As it can be seen on the average column the most important demanded quality for the customers is taking in care all the technical aspects, with a valuation of almost double the next highest demanded quality. This means considering all the necessary technical requirements of the product to deal the best with all electronic equipment stored inside. However, other aspects as good devices organization inside the rack are also important, which means paying attention to the structure. The structure holds all this equipment and protects all the devices. After ranking the demanded qualities, it is necessary to rank the requirements of each one.

- **Structure:** as it appears on the ranking, this demanded quality is the second most important for the design of the product. It has its logic, as it has an important roll inside the product functions.

	Hard and resistant structure	Sustainable / recyclable structure	Working in high temperatures	Impermeable	Sound proof	Fire proof
Hard and resistant structure	1	5	2	0,5	5	0,2
Sustainable and recyclable structure	0,2	1	0,14	0,33	3	0,14
Working in high temperatures	0,5	7	1	0,33	7	0,33
Impermeable	2	3	3	1	7	0,2
Soundproof	0,2	0,33	0,14	0,14	1	0,11
Fireproof	5	7	3	5	9	1
Total	8,9	23,3	9,28	7,3	32	1,98

	Hard and resistant structure	Sustainable and recyclable structure	Working in high temperatures	Impermeable	Soundproof	Fireproof	Row Avg.	Legible AVg.	Importance
Hard and resistant structure	0,11	0,21	0,22	0,07	0,16	0,10	0,14	0,44	0,06
Sustainable and recyclable structure	0,02	0,04	0,02	0,05	0,09	0,07	0,05	0,44	0,02
Working in high temperatures	0,06	0,30	0,11	0,05	0,22	0,17	0,15	0,44	0,07
Impermeable	0,22	0,13	0,32	0,14	0,22	0,10	0,19	0,44	0,08
Soundproof	0,02	0,01	0,02	0,02	0,03	0,06	0,03	0,44	0,01
Fireproof	0,56	0,30	0,32	0,68	0,28	0,51	0,44	0,44	0,19
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-	-

- **Technical aspects:** as it appears is the most relevant of demanded qualities. It is not strange to find this group of requirements at the top, as includes the most important aspects to take in mind. All the equipment needs to be correctly organized to facilitate all the manipulation as well as the replacement work of the workers in case of damage of some of the parts.

	Maximize load capacity	Visibility of the interior	Light weight	Easy distribution of devices	Good cable administration	Opening 360°/ easy access to devices	Visible electrical connexions
Maximize load capacity	1	7	3	0,33	3	0,33	0,5
Visibility of the interior	0,14	1	0,2	0,2	0,33	0,2	5
Light weight	0,33	5	1	0,33	0,33	0,2	0,5
Easy distribution of devices	3	5	3	1	0,5	1	3
Good cable administration	0,33	3	3	2	1	0,33	1
Opening 360°/ easy access to devices	3	5	5	1	3	1	3
Visible electrical connexions	2	0,2	2	0,33	1	0,33	1
Total	9,8	26,2	17,2	5,19	9,16	3,39	14

Following the same procedure all the ranking data has to be normalized in order to get the information at the same level.

	Maximize load capacity	Visibility of the interior	Light weight	Easy distribution of devices	Good cable administration	Opening 360°/easy access to devices	Visible electrical connexions	Row Avg.	Legible AVg.	Importance
Maximize load capacity	0,10	0,27	0,17	0,06	0,33	0,10	0,04	0,15	0,44	0,07
Visibility of the interior	0,01	0,04	0,01	0,04	0,04	0,06	0,36	0,08	0,44	0,03
Light weight	0,03	0,19	0,06	0,06	0,04	0,06	0,04	0,07	0,44	0,03
Easy distribution of devices	0,31	0,19	0,17	0,19	0,05	0,29	0,21	0,20	0,44	0,09
Good cable administration	0,03	0,11	0,17	0,39	0,11	0,10	0,07	0,14	0,44	0,06
Opening 360°/ easy access to devices	0,31	0,19	0,29	0,19	0,33	0,29	0,21	0,26	0,44	0,11
Visible electrical connexions	0,20	0,01	0,12	0,06	0,11	0,10	0,07	0,10	0,44	0,04
Total	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	-	-

- Maintenance and replacement: this demanded quality includes all the issues related with job of product's maintenance as well as all the issues related with the repairing of it. The replacement task the cost of the components has to be taken into consideration as it has an important roll.

	Easy replacement	Easy maintenance	Economic prize replacements
Easy replacement	1	0,2	2
Easy maintenance	5	1	9
Economic prize replacements	0,5	0,11	1
Total	6,5	1,31	12

-

	Easy replacement	Easy maintenance	Economic prize replacements	Row. Avg	Legible Avg.	Import.
Easy replacement	0,15	0,15	0,17	0,16	0,06	0,01
Easy maintenance	0,77	0,76	0,75	0,76	0,06	0,05
Economic prize replacements	0,08	0,08	0,08	0,08	0,06	0,00
Total	1,00	1,00	1,00	1,00	-	-

Secondary Systems: all the current products, a part from their basic needs, have to be complemented with external help or complements if their work requires it.

	Mobility system	Access control	Physical devices Protection	Interior lighting	Automatic Cooler system
Mobility system	1	0,2	0,14	0,14	0,14
Access control	5	1	0,14	0,11	0,14
Physical protection	7	7	1	2	5
Interior lighting	7	9	0,5	1	0,2
Automatic cooler system	7	7	5	7	1
Total	27	24,2	6,78	10,25	6,48

	Mobility system	Access control	Physical devices Protection	Interior lighting	Automatic Cooler system	Row. Avg	Legible Avg.	Import.
Mobility system	0,04	0,01	0,02	0,01	0,02	0,02	0,09	0,002
Access control	0,19	0,04	0,02	0,01	0,02	0,06	0,09	0,005
Physical protection	0,26	0,29	0,15	0,20	0,77	0,33	0,09	0,030
Interior lighting	0,26	0,37	0,07	0,10	0,03	0,17	0,09	0,015
Automatic cooler system	0,26	0,29	0,74	0,68	0,15	0,42	0,09	0,038
Total	1,00	1,00	1,00	1,00	1,00	1,00	-	-

- **Aesthetics:** this demanded quality is the sum of the above demanded qualities, as resumes all the needed requirements to adapt the product to them. It includes aesthetics aspects in the majority.

	Dimensions adapted to human limitations	Minimum space occupied	Little visual impact	Basic design
Dimensions adapted to human limitations	1	0,33	5	7
Minimum space occupied	3	1	3	3
Little visual impact	0,2	0,33	1	7
Basic design	0,14	0,33	0,14	1
Total	4,34	1,99	9,14	18

	Dimensions adapted to human limitations	Minimum space occupied	Little visual impact	Basic design	Row. Avg	Legible Avg.	Import.
Dimensions adapted to human limitations	0,23	0,17	0,55	0,39	0,33	0,03	0,010
Minimum space occupied	0,69	0,50	0,33	0,17	0,42	0,03	0,013
Little visual impact	0,05	0,17	0,11	0,39	0,18	0,03	0,005
Basic design	0,03	0,17	0,02	0,06	0,07	0,03	0,002
Total	1,00	1,00	1,00	1,00	1,00	-	-

- **Assembly and use:** this demanded quality includes all the aspects related with all the actions that the customers have to take to get the product ready for its use. It is an important demanded quality for the design because taking all this in care increases the customer's satisfaction.

	Easy to assemble	Easy assembly instructions	Easy to use/intuitive
Easy to assemble	1	3	3
Easy assembly instructions	0,33	1	0,2
Easy to use/intuitive	0,33	5	1
Total	1,66	9	4,2

	Easy to assemble	Easy assembly instructions	Easy to use/intuitive	Row AVg	Legible Avg	Import.
Easy to assemble	0,60	0,33	0,71	0,55	0,12	0,07
Easy assembly instructions	0,20	0,11	0,05	0,12	0,12	0,01
Easy to use/intuitive	0,20	0,56	0,24	0,33	0,12	0,04
Total	1,00	1,00	1,00	1,00	-	-

To make it easy, all the information of the tables is collected in a general one:

PRIMARY		SECONDARY	RowAvg.	Imp.
TECHNICAL ASPECTS	0,44	Maximize load capacity	0,15	0,07
		Visibility of the interior	0,08	0,03
		Light weight	0,07	0,03
		Easy distribution of devices	0,20	0,09
		Good cable administration	0,14	0,06
		Opening 360°/easy access to devices	0,26	0,11
		Visible electrical connexions	0,10	0,04
MAINTENANCE AND REPLACEMENT	0,06	Easy replacement	0,16	0,01
		Easy maintenance	0,76	0,05
		Economic prize replacements	0,08	0,00
ASSEMBLY AND USE	0,12	Easy to assemble	0,55	0,07
		Easy assembly instructions	0,12	0,01
		Economic price replacements	0,33	0,04
SECONDARY SYSTEMS	0,09	Mobility system	0,03	0,002
		Access control	0,07	0,005
		Physical protection	0,46	0,030
		Interior lighting	0,13	0,015
		Automatic cooler system	0,30	0,038
STRUCTURE	0,25	Hard and resistant structure	0,14	0,06
		Sustainable and recyclable structure	0,05	0,02
		Working in high temperatures	0,15	0,07
		Impermeable	0,19	0,08
		Soundproof	0,03	0,01
		Fireproof	0,44	0,19
AESTHETICS	0,03	Dimensions adapted to human limitations	0,33	0,010
		Minimum space occupied	0,42	0,013
		Little visual impact	0,18	0,005
		Basic design	0,07	0,002

In white colour there are marked the demanded quality with the highest rate of importance to make it clear for future steps in the QFD design methodology. These will be the most important and the one's that it is going to focus the study of redesigning the rack.

HOUSE OF QUALITY

DEMANDED QUALITIES

The list of demanded qualities for the customer is the listed below:

DEMANDED QUALITY	% importance
Maximize load capacity	**7**
Easy distribution of devices	**9**
Opening 360°/easy access to devices	**11**
Easy maintenance	**5**
Easy to assemble	**7**
Physical protection	**3**
Interior lighting	**1,5**
Automatic cooler system	**3,8**
Hard and resistant structure	**6**
Working in high temperatures	**7**
Impermeable	**8**
Fireproof	**19**
Dimensions adapted to human limitations	**1**
Minimum space occupied	**1,3**

QUALITY PLANNING TABLE

QUALITY PLANNING TABLE (I)

RACK 19” manufacturers – RETEX competitors			
Competitor 1	**Competitor 2**	**Competitor 3**	**Competitor 4**
			

Table 3 – Rack competitors

DEMANDED QUALITIES	Importance (up to 100)	CUSTOMER EVALUATION				
		Customer Opinion	**Competitor 1**	**Competitor 2**	**Competitor 3**	**Competitor 4**
Maximize load capacity	**7**	2	2	3	2	2
Easy distribution of devices	**9**	3	3	2	4	2
Opening 360°/easy access to devices	**11**	2	2	3	2	4
Easy maintenance	**5**	4	4	4	2	3
Easy to assemble	**7**	3	5	3	5	4
Physical protection	**3**	5	5	5	4	5
Interior lighting	**1,5**	3	4	3	1	1
Automatic cooler system	**3,8**	4	2	4	3	4
Hard and resistant structure	**6**	3	3	3	4	5
Working in high temperatures	**7**	5	5	3	4	2
Impermeable	**8**	5	5	5	5	5
Fireproof	**19**	4	4	4	5	4
Dimensions adapted to human limitations	**1**	5	5	4	5	5
Minimum space occupied	**1,3**	3	1	4	3	4
CUSTOMER WEIGHTED SATISFACTION		310	322	312	338	321

QUALITY PLANING TABLE (II)

DEMANDED QUALITIES	Importance (up to 100)	Customer Opinion	Competitor 1	Competitor 2	Competitor 3	Competitor 4	Target performance	Ratio of improvement	Sales points	DQ Composite Import.	% Composite Import.
Maximize load capacity	**7**	2	2	3	2	2	2	1,0	1	7,0	5,9
Easy distribution of devices	**9**	3	3	2	4	2	3	1,0	1,2	10,8	**9,1**
Opening 360°/easy access to devices	**11**	2	2	3	2	4	3	1,5	1	16,5	**13,9**
Easy maintenance	**5**	4	4	4	2	3	4	1,0	1,5	7,5	6,3
Easy to assemble	**7**	3	5	3	5	4	5	1,7	1,2	14,0	**11,8**
Physical protection	**3**	5	5	5	4	5	5	1,0	1,5	4,5	3,8
Interior lighting	**1,5**	3	4	3	1	1	4	1,3	1,2	2,4	2,0
Automatic cooler system	**3,8**	4	2	4	3	4	5	1,3	1,2	5,7	4,8
Hard and resistant structure	**6**	3	3	3	4	5	3	1,0	1,2	7,2	6,1
Working in high temperatures	**7**	4	5	3	4	2	5	1,3	1,5	13,1	**11,1**
Impermeable	**8**	5	5	5	5	5	5	1,0	1	8,0	6,8
Fireproof	**19**	4	4	4	5	4	4	1,0	1	19,0	**16,0**
Dimensions adapted to human limitations	**1**	5	5	4	5	5	5	1,0	1	1,0	0,8
Minimum space occupied	**1,3**	3	1	4	3	4	4	1,3	1	1,7	1,5
CUSTOMER WEIGHTED SATISFACTION		310	322	312	338	321	349				

PERFORMANCE MEASURES

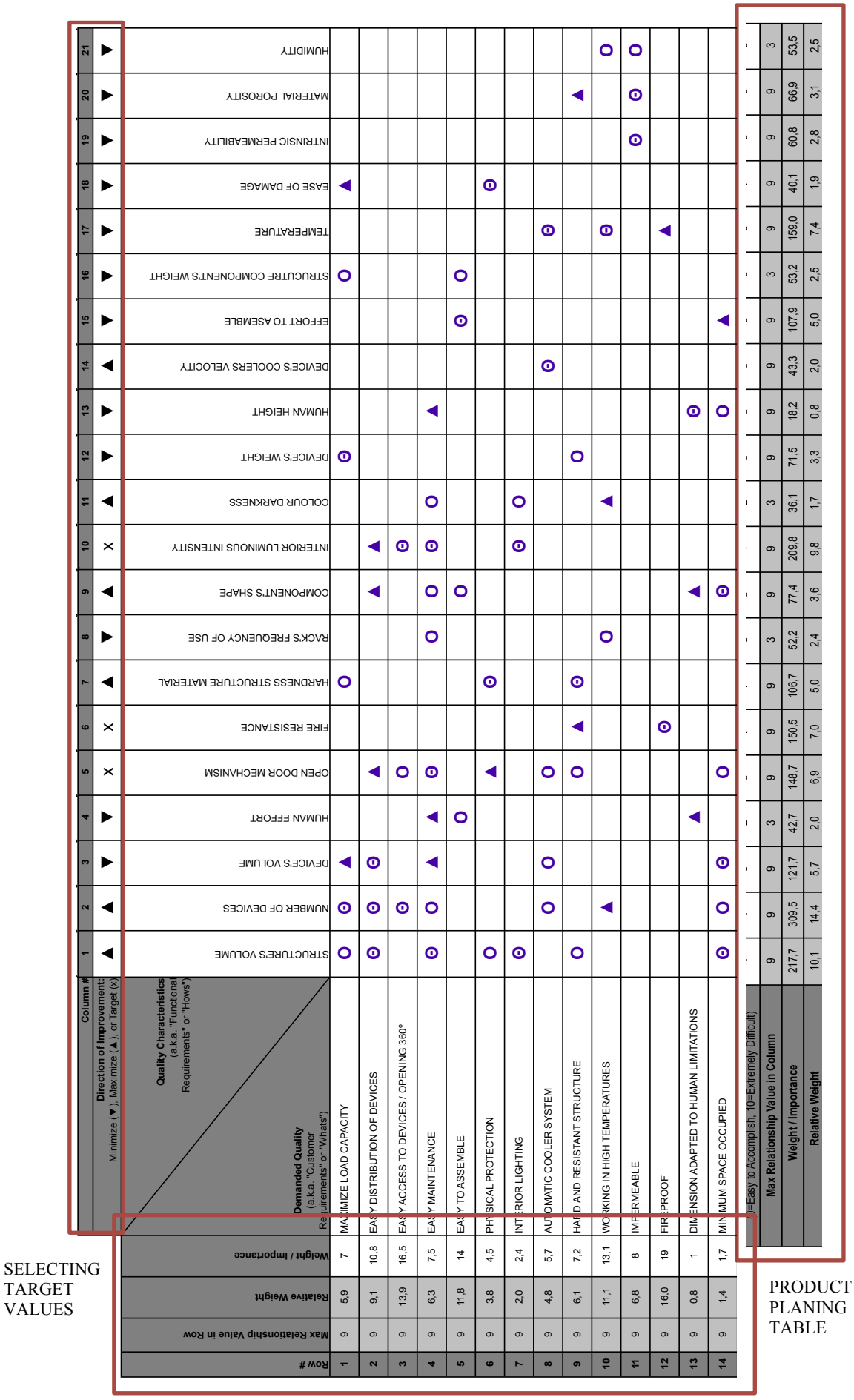
DEMANDED QUALITIES	PERFORMANCE MEASURES[3]
Maximize load capacity	Structure volume
	Number of devices
	Devices weight
	...
Easy distribution of devices	Structure volume
	Number of devices
	Devices volume
Opening 360°/easy access to devices	Human effort
	Number of devices
	Open door mechanism
Easy maintenance	Structure material
	Number of devices
	Rack's frequency of use
	Human effort
Easy to assemble	Components shape
	Effort to assemble
	Component's Weight
Physical protection	Structure volume
	Structure material
	Ease of damage
Interior lighting	Luminous intensity
	Structure volume
	Dark colour level
Automatic cooler system	Temperature
	Device's coolers velocity
Hard and resistant structure	Structure material
	Devices weight
Working in high temperatures	Temperature
Impermeable (cm^2)	Intrinsic permeability
	Material porosity
	Humidity
Fireproof	Fire resistance
Dimensions adapted to human limitations	Human height
	Human effort
Minimum space occupied	Device's Volume
	Number of devices

[3] Each demanded quality has more than the performance measures, as it will be seen on the matrix relationship in future pages, but here is only listed some of them as and example

RELATIONSHIP MATRIX

Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	STRUCTURE'S VOLUME	NUMBER OF DEVICES	DEVICE'S VOLUME	HUMAN EFFORT	OPEN DOOR MECHANISM	FIRE RESISTANCE	HARDNESS STRUCTURE MATERIAL	RACK'S FREQUENCY OF USE	COMPONENT'S SHAPE	INTERIOR LUMINOUS INTENSITY	COLOUR DARKNESS	DEVICE'S WEIGHT	HUMAN HEIGHT	DEVICE'S COOLERS VELOCITY	EFFORT TO ASEMBLE	STRUCUTRE COMPONENT'S WEIGHT	TEMPERATURE	EASE OF DAMAGE	INTRINSIC PERMEABILITY	MATERIAL POROSITY	HUMIDITY
MAXIMIZE LOAD CAPACITY	O	Θ	▲				O					Θ				O		▲			
EASY DISTRIBUTION OF DEVICES	Θ	Θ	Θ		▲				▲	▲											
EASY ACCESS TO DEVICES / OPENING 360°		Θ			O					Θ											
EASY MAINTENANCE	Θ	O	▲	▲	Θ			O	O	Θ	O		▲								
EASY TO ASSEMBLE				O					O						Θ	O					
PHYSICAL PROTECTION	O				▲		Θ											Θ			
INTERIOR LIGHTING	Θ									Θ	O										
AUTOMATIC COOLER SYSTEM		O	O		O									Θ			Θ				
HARD AND RESISTANT STRUCTURE	O				O	▲	Θ					O								▲	
WORKING IN HIGH TEMPERATURES		▲						O			▲						Θ				O
IMPERMEABLE																			Θ	Θ	O
FIREPROOF						Θ											▲				
DIMENSION ADAPTED TO HUMAN LIMITATIONS				▲					▲				Θ								
MINIMUM SPACE OCCUPIED	Θ	O	Θ		O				Θ				O		▲						

PRODUCT PLANING TABLE AND SELECTING TARGET VALUES

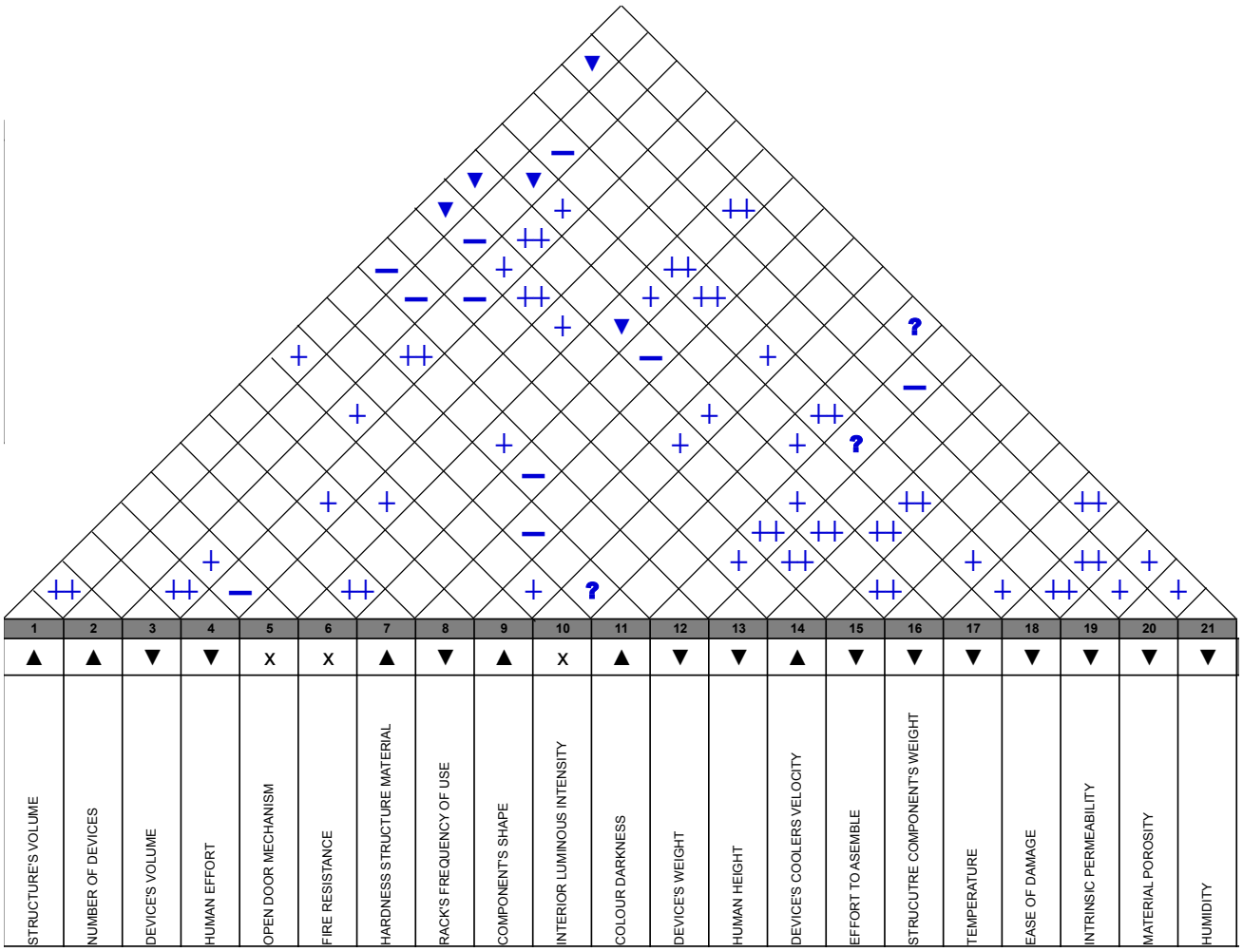


SELECTING TARGET VALUES

PRODUCT PLANING TABLE

IDENTIFYING PERFORMANCE MEASURE CONFLICTS

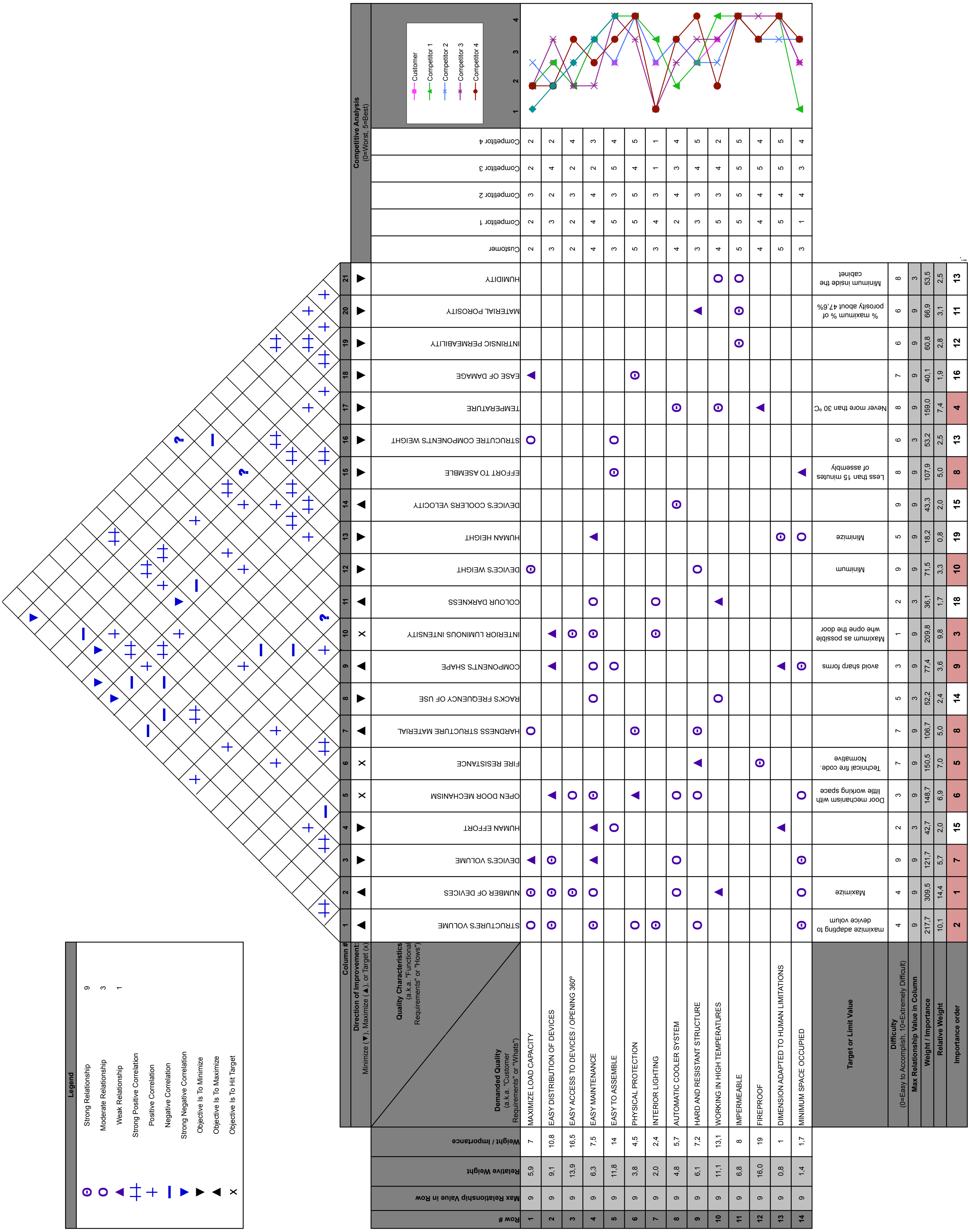
This is the result of analysing the relation between each pair of performance measures to determine the possible conflicts.



Conflicts:

- Structure Volume with: human height, effort to assemble, structure component's weight and material porosity.
- Number of devices with: human height, effort to assemble, temperature and ease of damage.
- Devices volume with: device cooler's velocity.
- Human effort with: open door mechanism.
- Fire resistance with: structure component's weight.
- Hardness structure material with: device's weight and structure component's weight.
- Rack's frequency of use with: colour darkness.
- Device's weight with: material porosity.

HOUSE OF QUALITY



CONCLUSIONS

FINAL PERFORMANCE MEASURES

The House of Quality gives the final design requirements to innovate the rack Login 2 studied taking care of all the information got from customer desires. The final performance measures are ranked according to the QFD importance of each into the final design. So, the final performance measures are:

1. **Number of devices**: the aim is to maximize this quantity with the minor space possible.
2. **Structure Volume:** maintaining a strong concept relation with the previous performance measure, this time the aim is to minimize the volume of the physic structure storing the maxim number of devices inside. Has to be reached an equilibration between both measures.
3. **Interior luminous intensity:** as particular demanded quality from the customer, seems to get quite importance for the new design. Having a lighting system inside the cabinet facilitates many duties such as maintenance, assembly, device's location, outside visibility and the possibility to act in case of a light blackout. Seemed to be stupid including this system but, in fact, resolves most particular problems.
4. **Temperature:** the target is to minimize heat inside the cabinet in order to reduce temperature. The convection of heat realized by cooler system inside the devices sometimes is insufficient to deal with the heat produced and an external system might be installed to do the extra work.
5. **Fire resistance**: working with electricity gives an added value of risk for accidents because of sparks and electrical failures. Must be found a material or coating that ensures the best possible protection to avoid any damage to electronic equipment.
6. **Open door mechanism:** there exist infinite door mechanisms that can suit the product. But, only some of them can fill other needed performance measures, such as minimizing the space occupied by the rack when it comes to its use. Nowadays, the major racks have front crystal or plastic door opening mechanism, with no other ways of design.
7. **Device's volume:** together with other two performances aforementioned, is an important measure to take in care. However, it leaves our work area design teams and

the rack is always appropriate to them and redesign them, would be another type of study would be related to the performed here.

8. **Hardness structure material:** every device inside the cabinet can reach the 5 kg depending of its size so the structure material has to be tough and resistant, fire resistance, impermeable and as heat resistant as possible. All these characteristics are related with the previous performance measures of fire resistance, permeability and temperature.
9. **Effort to assemble:** at first sight, can seem unimportant but is as important as the fact of minimize the structure volume and others actions. Assembly is an inevitable step before using the rack if the company wants to economize in transportation logistics dividing the product in components. For this, the effort to assemble has to be minimized and complemented as far as possible with assembly instructions.
10. **Components Shape:** this aspect is more particular than the others. The shape of the different components that form the rack structure can influence in many other demanded qualities, such as structure volume, basic design or opening door mechanism.

SUGGESTION OF SOLUTIONS

Once the final product performances are ranked it is time to find market solutions for the ones missing on the current Logic 2. In resume, is going to be suggested possible solutions options for the missing target values form the list below in order to finally optimize the rack Logic 2.

INTERIOR LUMINOUS INTENSITY

The solution consists on installing 4 vertical columns of cold white LEDS at the exterior rack structure, located on the 4 corners formed by the two wall junctions each. Its location is an important point to optimize their luminosity. The specifications are:

Consume: 24W
Colour Temperature: Cold white
Useful life: 50.000 hours
Warranty: 2 years
Number of LEDs: 300
Type of LED: SMD 3528
Working temperature: -30ºC - +60ºC
Voltage: 12V DC.

FIGURE 16 – Cold White LED ilumination *Source [11]*

OPEN DOOR MECHANISM

The solution is to install a shutter door mechanism opening instead of the current front door mechanism opening in order to minimize the space occupied when you open the rack to manipulate the equipment inside. When it comes to open the rack, would be less human effort as well as a reduction of the used manipulating area. Made of aluminium, as well as the original material structure material, this kind of opening system also helps to the inside refrigeration. Another possibility is installing the same blind but with holes, which would assist even more the cooling issue.

FIGURE 17 – Roller blind ***Source [12]***

OPENING 360º

The idea of designing the rack as a complete opened wall structure becomes an innovative system, thought as if were independent doors each other. All are advantages: would facilitate the maintenance, the access to devices and would give a 360° vision of the product from all angles of the room where is located.

SUGGESTIONS FOR FUTUR STUDIES

Regarding possible future work and achievements in the project, there are two clear lines of improvement:

- Applying the TRIZ principles to find possible contradictions using the 40 principles of study.
- Applying the QFD method again once the prototype is tested in all the areas of application and look if there is any other possible innovative incorporation to improve the product even more.
- Implementing the manufacturing process indications and, if it is necessary, try to find the designing errors as well as fabrication errors using the FMEA methodology.

BIBLIOGRAFY

Source [1]: http://www.quiminet.com/articulos/la-importancia-del-uso-de-racks-como-un-sistema-de-almacenaje-44222.htm

Source [2]: ROZENFELD, Henrique; *Gestão de Desenvolvimento de Produto Brasil* (2010).

Source [3]: G. DAY, Ronald; *Quality Function Deployment. Linking a Company with Its Customers* (1993)

Source [4]: TAMAYO, Francisco y GONZÁLEZ, Verónica. ¿Que es el QFD? Descifrando el Despliegue de la Función de Calidad; http://www.qfdlat.com

Source [5]: http://www.qfdi.org/what_is_qfd/faqs_about_qfd.htm

Source [6]: TERNINKO, John; *Step-by-Step QFD. Customer-Driven Product Design. Second Edition* (1997)

Source [7]:http://www.retex.es/es/Racks/Racks-y-accesorios-para-cableado/Logic-2-Rack.axd

Source [8]: http://www.qfdlat.com/Herramientas_QFD/herramientas_qfd.html

Source [9]: http://www.hooping.net/glossary/rack-99.aspx

Source [10]: FRANZINI, R. e DOSSI, E. – Alunos da EESC-USP, Dep. Eng. Mecânica, Sao Carlos, SP; supervised by NÓBREGA, K.C. – Professor da EESC-USP, Dep. Eng. Mecânica, Sao Carlos, SP;

Source [11]: http://www.belednos.com/Productos/Tira_LED

Source [12]: http://aluminioscarpal.com/pers_enrollables.html

ANNEXS

ANNEX I: QUESTIONNAIRE MODEL

First of all thank the dedicated time to answer these questions that follow as a great help to develop my research re-design of RACK as a final project in Industrial Engineering.

FUNCTIONALITY

1. "Your company use racks?
If you do not use, explain why.

2. "Could you list what functions or benefits provides the rack in your area of application or business?

3. "Is there any functionality you miss?

4. "You will find useful in situations that would the rack have any shift system to move from one place to another?

TECHNICALITIES

1. "The ventilation from the electronic devices is sufficient for proper ventilation around the RACK?
If you have a rack with cooling system say which type of cooling system is.

2. "Do you think the layout of the servers and all the electronic devices are ideal for handling?

3. "It would be a better arrangement of horizontal machines?

4. "Think of all the fixation devices are secure enough to withstand several times and movements?

5. "We found that the standardized dimensions of the current cabinet to fit properly so that you would give?

6. "We can easily see performance indicators from all angles of front?